NIWA
Taihoro Nukurangi

The status of longfin eels in New Zealand - an overview of stocks and harvest

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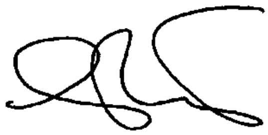


Marty Bonnett

Executive summary

The longfin eel, *Anguilla dieffenbachii* is found only in New Zealand (endemic). While they frequently coexist with shortfin eels (*A. australis)*, longfins have a wider distribution than shortfins, being found mainly in flowing water from estuaries to high country lakes. They grow to a larger size than shortfins, with females reaching 2.0 m and 25+ kg. Growth rates are generally slow, averaging 2-3 cm/year, although the species can grow much more rapidly in warm and food-rich environments. At seaward spawning migration, males are typically ~25 years old, and females >40. Longfins are our most ubiquitous native fish, and usually dominate the biomass of fish in a given area. They are an important part of the freshwater ecosystem for intrinsic reasons (endemic species), ecological reasons (apex predators and scavengers), customary reasons (extremely important to Māori in legends and whakapapa and as a food source), and commercial reasons (support a significant commercial fishery).

There is increasing concern about the status of longfin stocks. The commercial fishery is well-established, and very efficient. Eels entered the Quota Management System in 2000 (South Island) and 2004 (North Island). South Island quota is not allocated by species, whereas North Island quota is. Longfins comprise about 1/3 of the total commercial eel catch of ~ 500 t, with North Island catches being about twice those of South Island catches. Longfins dominate catches in Rangitikei-Wanganui, and Taranaki in the North Island , and in the West Coast, Otago and Southland in the South Island.

While both eel species have been detrimentally affected by river channelization, wetland drainage etc, being the species that penetrates furthest inland, longfins have been more affected by dams and weirs than shortfins. Dams have historically impeded upstream migrations of juvenile eels (elvers), although most large dams now have elver trap-and-transfer facilities whereby juvenile eels are caught at the base of the dam and manually transferred upstream. However, downstream passage of maturing adults is much more difficult to facilitate, and passage through turbines is almost invariably fatal for female longfins. Estimates of total hydro mortality are of the order of 10-20% of the total commercial longfin catch.

Arguably, the most important indicator of stock wellbeing is juvenile recruitment, and unfortunately, New Zealand has inadequate records of this. Limited glass eel sampling (1995 – 2006) did not indicate any change in glass eel abundance at the 6 sites monitored, although there is evidence of a decline in glass eel recruitment to the Waikato River (which has the largest glass eel run of any New Zealand river). Data on elvers at hydro dams are also relatively short-term (7-16 years), and show no significant trends, although recruitment of longfin to some large rivers is particularly low. However, from electric fishing samples, there was clear evidence of an overall lack of juvenile longfins at sites in both islands, but especially from the South Island. Likewise the records of longfin eels entered onto the New Zealand Freshwater Fish database has shown a dramatic decline in recent years, indicative of an overall decline in the distribution of longfins.

Catch-per-unit-effort data from the commercial fishery differ between the islands, with North Island data showing strong evidence of declines (1990-2007), while South Island data show no such decline (although overall catches have dropped). Changes in the size grades of harvested eels are difficult to interpret as they are influenced by such things as changes in fishery regulations and market demands, and the data are often not able to be separated by species. However, given the vulnerability of large eels to fyke netting (where trials have shown a single night's fishing can harvest ¾ of the estimated eel population within the fished area), it is suggested that the reduced abundance of larger eels is largely a consequence of commercial fishing.

Historically there were 23 licenced processing factories, but today there are only 4 or 5. Almost all commercially harvested eel is exported, although the species are not usually differentiated. Whole frozen eel is still the main export category, followed by live eels. Traditional markets have been Belgium, Germany, the United Kingdom, and Netherlands, although over the past few years exports to Korea have increased dramatically and in 2010, ¾ of all New Zealand eel was exported to this country.

Partly because of concerns expressed at the annual Eel Working Group (convened by the Ministry of Fisheries), the quota for North Island longfin was reduced by an average of 58% in 2007/08. Over the past few years, the Working Group has consistently raised concerns about the status of longfins, and the commercial fishery has imposed some voluntary constraints, also in recognition that some regions are showing depletion of longfins. A summary of the indicators of the status of longfins indicates a number of perceived substantial negative changes, indicative of a stock that has become seriously depleted. While many of the life-history characteristics of longfins like slow growth but achievement of considerable size at maturity, and semelparity (spawn once at maximum size/age), have been successful strategies over evolutionary time scales, they are not features that provide resilience to sustained harvest.

1 Outline of the contract

NIWA were commissioned by the Parliamentary Commissioner for the Environment to provide an overview of the New Zealand freshwater eels fisheries that highlighted the status and management of longfin eels.

The objectives of the review were to

1. Describe the eel industry in New Zealand.

   Draw on previous knowledge and experience, including anecdotal evidence where appropriate. Include nature of domestic and international markets (including what attracts a premium price), who is involved in processing and where they are located. Draw distinctions between shortfin and longfin and identify other relevant factors.

2. Provide an overview of the data analysis and reasoning that the Ministry of Fisheries uses to justify the current management of long finned eel stocks.

   Include an assessment and summary of relevant data, distinguishing clearly between what can be said with reasonable confidence and what cannot be said.

3. Identify possible changes to practices and regulations that would lead to more sustainable management of long finned eels.

   Include supporting data analysis and rationale.

4. Estimate the number of eels killed in hydro stations and compare this to the number killed by “commercial harvest.”

2 Species and distribution

New Zealand has two main species of freshwater eel, the shortfin eel (*Anguilla australis*), which is also found in southeastern Australia and some Pacific Islands, and the endemic longfin eel (*A. dieffenbachii*) (McDowall, 1990). In 1996, a third species, the Australian longfin eel, *A. reinhardtii*, was found in the northern parts of the North Island (Jellyman *et al.*, 1996). Although it appears to be a reasonably frequent immigrant, this last species is not a significant component of the New Zealand eel biomass.

Like freshwater eels worldwide, the New Zealand species are assumed to be panmictic i.e. they consist of single genetic stock despite occupying broad geographic ranges. Shortfins from Australia and New Zealand show small but significant differences in morphology (Jellyman, 1987; Watanabe *et al.*, 2006), but genetic homogeneity (Dijkstra and Jellyman, 1999; Smith *et al.*, 2001), at least at the glass eel stage. Whether these small morphological differences are a result of spawning in separate areas is unknown, but on the weight of current evidence this would seem unlikely, meaning that the species should be recognised and managed as a single trans-Tasman one. In contrast, the longfin is found only in New Zealand and its offshore islands, meaning there is no reserve stock or “buffer” should numbers on mainland New Zealand become seriously depleted.

The main species frequently coexist, but the shortfin is principally a lowland species, dominating populations in lowland lakes, estuaries and the lower reaches of rivers. It reaches a maximum size of about 1.1 m and 3 kg, compared with the 2.0 m and 25+ kg for the native longfin (Jellyman, 2003). The two species have different habitat preferences (Jellyman *et al.*, 2003). Longfins prefer flowing water and hence are found extensively in mainstem rivers; they penetrate long distances inland and inhabit high country lakes and rivers. Although juveniles of both species prefer shallow water (<0.5 m deep), juvenile shortfins prefer slow velocities (<0.5 m s^{-1}) and fine substrata, and juvenile longfins faster water (>0.5 m s^{-1}) and coarse substrata. Adults of both species prefer deep, slow-moving water, but shortfins again prefer finer substrata (mud) than longfins (coarse gravel and boulders). There is experimental evidence of shortfin glass eels making specific olfactory choices about the types of waterways they invade, but longfins appear indifferent to water type, a response in keeping with their broader habitat preferences (McCleave and Jellyman, 2002).

3 Importance

Eels are important parts of the freshwater ecosystem for the following reasons.

- Intrinsic importance – they are native to New Zealand, and in the case of the longfin, endemic to New Zealand.
- Ecological importance – they are our largest freshwater fish, and usually the most frequently encountered. They are the top (apex) predators in freshwater food webs. As opportunist scavengers, they dispose of and recycle many nutrients.
- Customary importance – eels (tuna) have huge significance to Māori, forming important parts of their whakapapa and legends, and as a readily available source of food.
- Commercial importance – eels maintain important commercial fisheries.

To amplify these comments for longfin eels:

3.1 Intrinsic importance

The longfin is by far the largest native freshwater fish in New Zealand waters. It is also the most frequently encountered species, as it has a very widespread distribution, and lives in a wide range of habitats. It is unique to New Zealand and may well be the world's largest freshwater eel. While not having the same appeal as many of the "charismatic megafauna" of New Zealand (being more of a "cold slimy" than a warm fluffy), eels are nonetheless part of our ecosystems and heritage. Most New Zealanders have an eel story somewhere in their background.

3.2 Ecological importance

The longfin has been described as an ecological generalist (Glova et al. 1998; Jellyman et al. 2003) as it is distributed from estuaries to the upper reaches of river systems, including source lakes. It will eat whatever food is available, and larger individuals will include fish in their diet. It has a very distensile stomach and can take large quantities of food – however, it can also survive long periods without feeding (many weeks) as it is "energetically conservative" and does not spend energy in holding a place in the current like many fish do, but rather utilises cover out of the flow (e.g. under banks or logs) or swims along the bottom of rivers taking advantage of the reduced water velocity. It can tolerate poorer water quality than many other species, including low levels of dissolved oxygen and elevated water temperatures.

Longfins often comprise > 90% of the overall biomass of fish in a given area. As an apex predator, they can prey on all other freshwater fish, including introduced species. Longfins control fish populations, including other eels. For instance, when large longfins were removed from a section of stream, smaller eels of both species moved into the area in considerable numbers (Chisnall et al. 2003) – obviously the presence of the larger eels was exerting a constraint on the distribution of smaller eels.

The diet of longfins varies with size (gape of the mouth). Small eels eat aquatic invertebrates – larval mayflies, caddisflies, snails etc. Once longfin reach 40 cm, they start to eat fish if available (Jellyman 1989). They are ambush predators, and use their prodigious sense of smell (equivalent to that of a bloodhound) to locate prey and sneak up on it from downstream.

Growth is generally slow, averaging 2-3 cm/year, with growth rates in the North Island being slightly faster than in the South Island. As a consequence, when they reach the minimum commercial size of 220 g, North Island longfins average 14 years of age in freshwater, while their South Island counterparts average 17.5 years (Jellyman 2009). Eels are a semelparous species, meaning that they spawn once at the end of their life - it is presumed they die after spawning as they do not feed during their 5-6 month oceanic journey to the spawning grounds, and aquarium observations indicate that they become increasingly emaciated as they mature. As with all freshwater eels, females grow to a much larger size than males. Sizes at maturity are given in Table 3-1.

Table 3-1: Average sizes and ages of migrating eels.

	Average length (cm)	Length range (cm)	Average weight (kg)	Typical age (years)
Shortfin				
Male	44	38 - 55	0.2	14
Female	74	50 - 110	0.8	25
Longfin				
Male	62	48 - 74	0.6	25
Female	115	75 - 180	4.0	40

For female eels, fitness/reproductive output is maximised by growing large as this results in much greater fecundity (production of eggs). As an apex predator, large longfin eels will have very low natural mortality as they have no natural predators– the maximum age of longfin females can exceed 100 years (Jellyman 1995). Such longevity may be a risk-minimising strategy by spreading the range of sizes at which different individual eels achieve maturity. While this longevity and semelparity have obviously been successful strategies over evolutionary time scales, they do not appear to be strategies well adapted to significant exploitation.

3.3 Customary importance

Prior to European settlement, Māori had a highly developed fishery for freshwater eels. In the absence of native mammals, eels were enormously important as a basic foodstuff, because they were widespread, abundant, easily caught, and capable of being preserved. As a result, Māori had an extensive knowledge of the ecology of eels, and developed effective fisheries for both species, harvesting feeding and silver (migrating) eels through combinations of traps, spearing, bait fishing, and large weirs (Downes, 1918; Best, 1929; McDowall, 1990, 2011).

Eels feature extensively in Māori mythology, large eels often being credited as spiritual guardians of waterways (Best, 1929). Wars were sometimes fought over the rights to fish for eels in particular rivers. Māori practised various forms of management, including imposing fishing bans on a waterway for ceremonial or conservation reasons, and seeding areas with small eels.

Although most of the present-day harvest by Māori utilizes European fishing techniques, some customary fisheries practices still operate. For example, in a small coastal lake (Wairewa/Lake Forsyth, 560 ha) in the South Island, migrating shortfin eels accumulate at a gravel bar separating the lake from the sea, where they are gaffed on dark nights when they enter drains dug into the gravel bar. Several hundred may be taken on a good night's fishing (Todd, 1978).

Both Wairewa and Lake Horowhenua (and outfall, Hokio Stream) were set aside as Māori eel fisheries (The Fisheries (Māori Eel Fisheries) Notice 1983). Since then, in recognition of the importance of eels to Māori, the Crown has set aside a number of waterways as non-commercial fisheries (rather than gazette these areas as exclusive customary-only fisheries). Currently these areas are:

A portion of Te Waihora/Lake Ellesmere (Canterbury) – (a further area is under negotiation now that the bed of the lake has been vested with Ngai Tahu)

Section of the Pelorus River (Marlborough)

Wainono Lagoon and Waihao River (South Canterbury)

Rangitata Lagoon (South Canterbury)

Ahuriri Arm of Lake Benmore (Otago)

Taharoa lakes (Kawhia)

Whakaki Lagoon (Hawke Bay)

Lake Poukawa (Hawke Bay)

Pencarrow lakes (Kohangapiripiri and Kohangatera) – (Wellington)

In addition, a section of 10 km in the Mataura River, Southland (below and including the Mataura Falls) has been set aside as a mataitai reserve in recognition of its important eel and lamprey (kanakana) fishery.

Māori have frequently expressed concern that commercial fishing has compromised their own ability to harvest sufficient quantities of large eels for ceremonial purposes, and that such land-use practices as wetland drainage and stream clearance have led to a significant degradation of eel habitat. There is also a general desire for eel stocks to be rebuilt to pre-commercial fishing levels, although unfortunately this would seem to be impossible because of irreversible land-use changes. In recognition of the reduced availability of longfin eels in some North Island areas, Māori eel fishers (and/or the quota holding company Aotearoa Fisheries Ltd) are voluntarily not fishing their longfin quota; similarly, Ngai Tahu have chosen not to fish their commercial quota (South Island) for a number of years.

3.4 Commercial importance

There was some interest in using oil extracted from eels as a source of vitamins during World War II (Shorland and Russell, 1948). Although eels were plentiful and the oil was a rich source of vitamins, this failed, probably because cheaper sources of fish oil became available from overseas (McDowall 1994). The commercial eel fishery really got underway in the early 1960's, with the arrival of Dutch immigrants who had both the knowledge of eel fisheries and the ability to make and use fyke nets (McDowall 1990). Within a few years, the status of eels to non-Māori rose from that of a nuisance species, to a valued commercial species. There has always been a viable commercial market for eels in Europe, and the first efforts of the fledgling New Zealand industry were directed to markets in Germany, Holland and the United Kingdom. Further comments on the development of the commercial fishery are contained in section 4.3.

Relative to other commercial fisheries, the eel fishery is neither large nor lucrative. As indicated in section 7.2, the total value of the fishery over the past 6 years has averaged $4.9m per year. Costs of eel quota varies with time and recently, North island quota has sold for $10 000 – 20 000/tonne, while South Island quota has been ~ $20 000/tonne. Present North island quota (TACC) is 347 t of shortfin and 82 t of longfin, while South island quota (both species combined) is 421 t; assuming an overall value of $20 000/tonne, the value of the commercial eel fishery is $17 m.

4 Exploitation of eels

Europeans have had a very different understanding of the importance of eels than Māori. To Europeans, eels were usually regarded as a pest species and were to be avoided. Early exploration and trade resulted in destruction of many Māori eel weirs so that boats could navigate rivers freely. Large areas of lowland wetland were progressively drained, and it is estimated that less than 10% of all wetlands remains from what was present when Europeans arrived in New Zealand a little over 200 years ago (McDowall 1990). Such large destruction of wetlands and river straightening has meant the loss of considerable habitat for eels, particularly shortfins. Being more of a species that favours flowing rivers and high country lakes, longfin eels have been more affected by the building of weirs and dams, as historically, no fish passes were provided. Indeed, it was usually considered to be a good thing to prevent eels from gaining access upstream, as longfins were known to be predators on brown and rainbow trout that were introduced to New Zealand in the late 1800's to help British settlers acclimatise to life in New Zealand. Both trout species established rapidly and were spread throughout the country, and form the basis of New Zealand's legendary wild trout fishery.

4.1 Eel destruction campaigns

Unfortunately, eels, especially larger longfins, were known to include trout in their diet. This angered many trout fishers, the Acclimatisation Societies (the managers of the trout fisheries), who spent a considerable amount of time and money rearing juvenile trout in hatcheries and releasing them into rivers around the country. Anglers were encouraged to kill as many eels as possible, and in the 1930's, eel destruction campaigns were started in some regions. Baited traps were used to catch eels.

During the 1960's, although the intensive eel destruction campaigns had finished, many regions still had a bounty on eels, to encourage young boys especially (including the author), to kill them. Research was carried out at this time on the effect of eels on a trout population. The results were a surprise to many trout anglers, as when eels were removed from the stream, the trout population increased almost 10 times, but the average size reduced to a size too small to be of interest to trout fishers (Burnet 1968). This showed that the presence of eels, especially longfins, was useful in stopping trout from over-populating, essentially helping to maintain a higher value trout fishery. In fact, in many of New Zealand's most highly regarded wild trout fisheries, eels and trout coexist, indicating that these species can live together (Jellyman, 1997). This knowledge effectively stopped the bounty system on eels.

4.2 Customary fisheries

As indicated in section 3.3, Māori have a long and substantial history of eel harvests. Although this is an oral tradition and catches are largely unquantified, there have been a number of observations of Māori fishing methods and seasons (e.g. Downes 1918, Best 1929), culminating in the most recent and comprehensive review of McDowall (2011). In this book, McDowall (2011) devotes almost 100 pages to describing the Māori tuna (eel) fisheries, and prefaces this by stating that "eels were the most important freshwater fish for traditional Māori exploitation, and clearly a taonga for Māori communities".

The extent of the present customary harvest is unknown. In a review of eel usage in the King Country (using a postal questionnaire), Maniapoto (1998) noted that capture and usage of tuna for customary purposes could be considerable – he estimated that the 45 marae in the rohe could need between 136 – 164 t per annum. When reviewing the fisheries of Te Waihoa/Lake Ellesmere, Jellyman and Smith (2008) noted that data supplied by Ngai tahu gave a customary harvest of tuna of up to 5 t per year from this lake. Collectively, however, there are no records of total customary harvest of eels from throughout New Zealand, but it is likely to be considerably less than the quantities allowed for within the QMS i.e. North Island 74 t of shortfins and 46 t of longfins; South Island 107 t (both species combined); Chatham Islands 3 t shortfin and 1 t longfin.

4.3 Development of the commercial fishery

The commercial eel fishery in New Zealand commenced in the early 1960s, and grew rapidly until annual catches of 2000 t were recorded in the early 1970s. Jellyman (2009) described development of the fishery in three phases: (i) an exploitation phase (1965–1980); (ii) a consolidation phase (1980–2000); and (iii) a rationalization phase (2000 on). The exploitation phase was characterized by rapid expansion of the industry, a proliferation of processing factories, and generally large export volumes of a relatively low-value product. There were few management constraints, and early concerns were more to do with the possible impact of fishing on the important recreational trout fishery than on eel stocks themselves. In the early 1990s, 23 processing factories operated (Jellyman, 1993), and there was no limit on catches or the number of commercial fishing licences issued. An initial minimum size of 150 g introduced in 1981 was increased to 220 g in 1992, in an endeavour to improve marketability and yield-per-recruit. To “cap” the escalating catches in Te Waihora/ Lake Ellesmere, then New Zealand's single largest eel fishery, the lake was declared a “controlled fishery” in 1978, and a (maximum) total allowable catch (TAC) was set for this lake.

During the consolidation phase, Government moved to reduce the pressure on eel stocks, because there were some concerns about localised overexploitation. Two important constraints were the exclusion of part-time commercial fishers from the industry (1982), and a freeze (moratorium) on the issuing of new licences in 1988. Associated with the licence freeze was a voluntary agreement by the eel industry not to increase fishing effort beyond that of the late 1980’s. To assist with this, a legal loophole that enabled multiple fishers to operate from a single fishing permit was closed in 1997. Towards the end of this phase, fishery managers encouraged cooperative management planning by industry and Māori, which resulted in a series of regional management plans for the South Island (Te Waka a Maui me ona Toka Mahi Tuna, 1996). These plans formed the information base required for the next phase, the entry of eels into the Quota Management System (QMS).

In the rationalization phase, South Island eels were introduced into the QMS in 2000, and a (maximum) TAC was set, with the commercial portion of this allocated to fishers largely on the basis of previous fishing history. The allocation of individual transferable quotas (ITQs) to fishers is considered to provide an incentive for conservation through the allocation of transferable rights to harvest in perpetuity (Batstone and Sharp, 1999). Similar to marine species, Māori received 20% of the commercial quota, and in recognition of the historical importance of eels to them, catch allocations were also made for customary purposes (another 20% of the TAC). South Island quota was set for both species combined, meaning that there is no segregation of quota by species; quota was allocated to six regions (ANG 11-16) with fishers often being permitted to fish in more than one region. While the lack of quota per species provides maximum flexibility for harvesting, it is viewed in the present report as distinct management disadvantage as it is not possible to specify given harvest levels of each species.

North Island eels entered the QMS in October 2004, catches again being allocated based on fishing history. In recognition that longfins were being harvested at a rate considered by fishery managers to be unsustainable, quota for that species was set at 18% less than recent commercial catches. Again, a substantial allowance was made for customary purposes (14% of TAC), and 11% for recreational eel fisheries. For management purposes, there are 4 stocks of shortfins (SFE 20-23) and four stocks of longfin (LFE 20-23) in the North Island. A recent development has been a marked reduction in the number of processing companies to two main ones, who also hold much of the quota for both islands. One of these companies is owned by Māori. In recognition that eel stocks in some regions are showing signs of significant depletion, eel fishers have sometimes voluntarily forgone opportunities to catch their annual entitlements to assist stocks to rebuild.

4.3.1 Current commercial fishery harvest

The Quota Management Areas and hence eel stock areas, are shown in Figure 4-1.

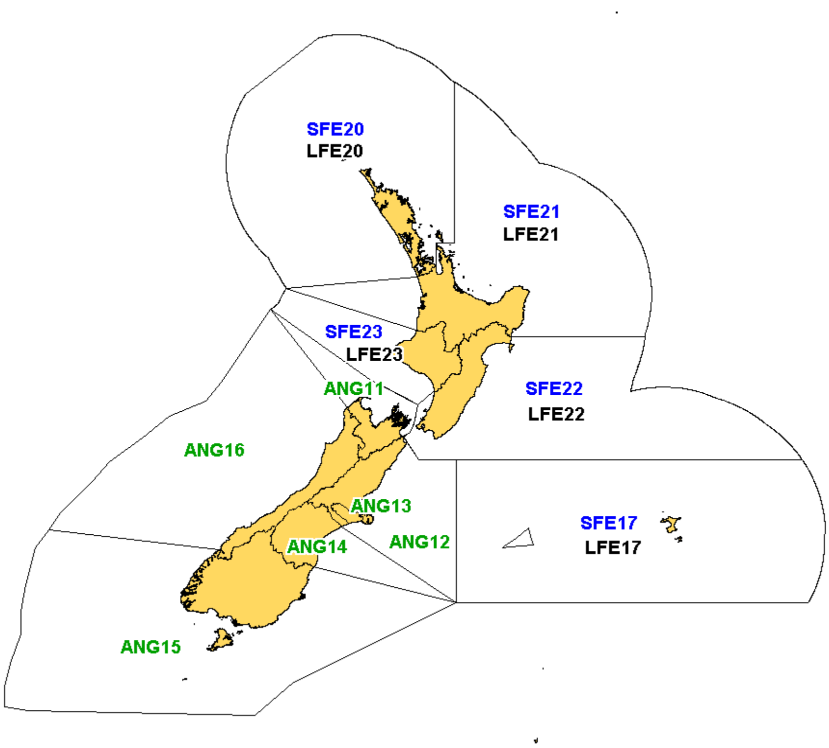


Figure 4-1: Quota Management Areas for the New Zealand eel fishery. Separate stocks are designated for shortfins and longfins in the North and Chatham Islands. South Island eel stocks are designated as a single stock (ANG) for both species combined.

For finer geographic level reporting, the Quota Management Areas are further divided into 25 Eel Statistical Areas (ESAs; Figure 4-2).

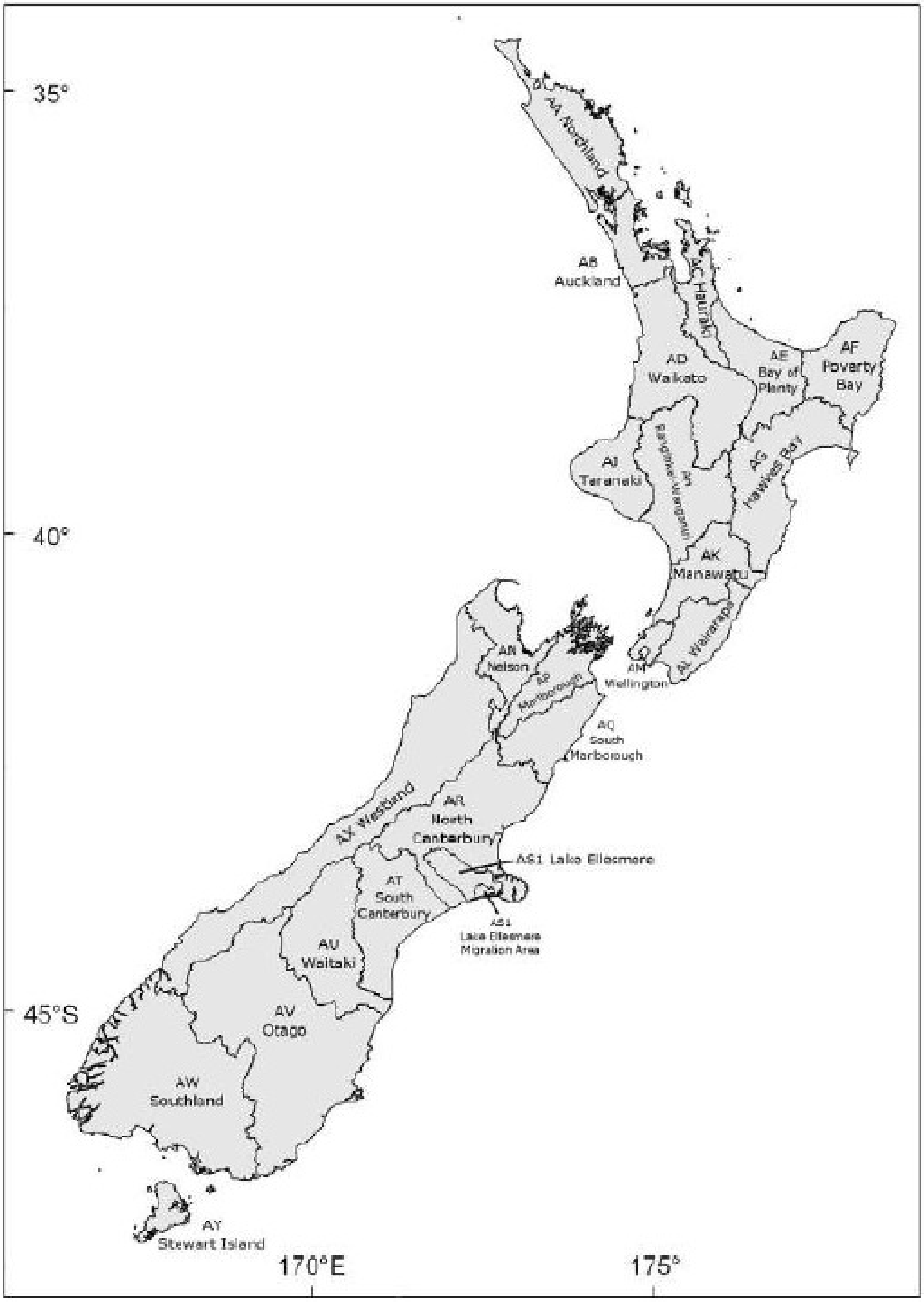


Figure 4-2: Eel statistical areas (ESAs) used for the reporting of commercial catch (Chatham Islands not shown).

More recently, MFish commissioned a study of further finer scale reporting areas (Beentjes 2008), that was more explicitly based on major catchments, and sub-divisions within these catchments (Figure 4-3). Most recent reports on catches by area have used this finer scale division (sub ESAs, Beentjes 2008) although catches can also be scaled-up to comply with both QMAs and ERAs.

Figure 4-3: Eel Statistical Areas (ESAs) and sub-ESAs used for collection of commercial catch information. Red lines (in use since 1983) denote ESAs, and purple lines (used by eel researchers since 2003) represent sub-ESAs. The ESA codes were updated from 2004, although the older references are used here in combination with the sub-ESA codes (from Beentjes 2008)..

Commercial eel fishers supply a monthly catch and effort return. These data are cross-checked against monthly returns from eel processors (Licensed Fish Receivers), and any significant discrepancies between the two datasets are investigated.

Reported commercial fishery catches (Figure 4-4) show the rapid increase in catches in the late 1960's to a peak of 2077 t in 1972, 25 years of markedly fluctuating catches, and a general decline since 1994/95 to currently a little over 500 t (Sullivan et al., 2010). Declines in the commercial catch since 2000 are attributable to the introduction of the QMS (and attendant loss of experienced fishers), varying overseas markets, some reductions in areas available to commercial fishers, droughts, the availability of eels, and more recently, because of voluntarily unfished quota . Shortfins have always been the dominant species, averaging 64% of the total catch over the past 30 years. Although longfins have sometimes contributed as much as 45% of the annual catch, their proportion over recent years has consistently been about one-third of the total catch. North Island catches have always exceeded South Island catches, the relative contributions over the past 14 years being 64% and 36%, respectively.

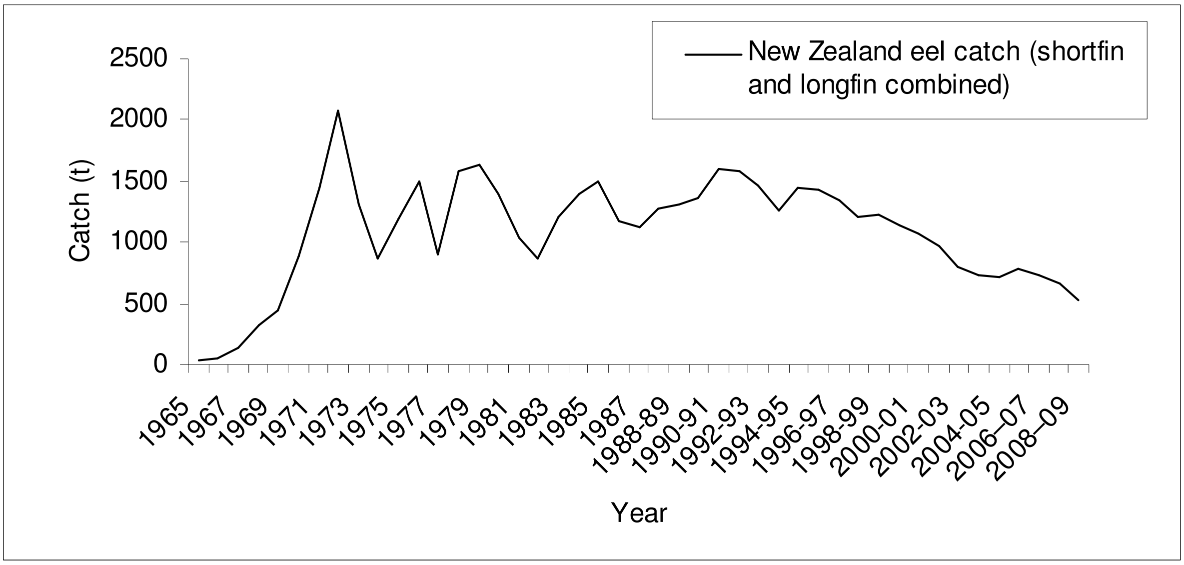
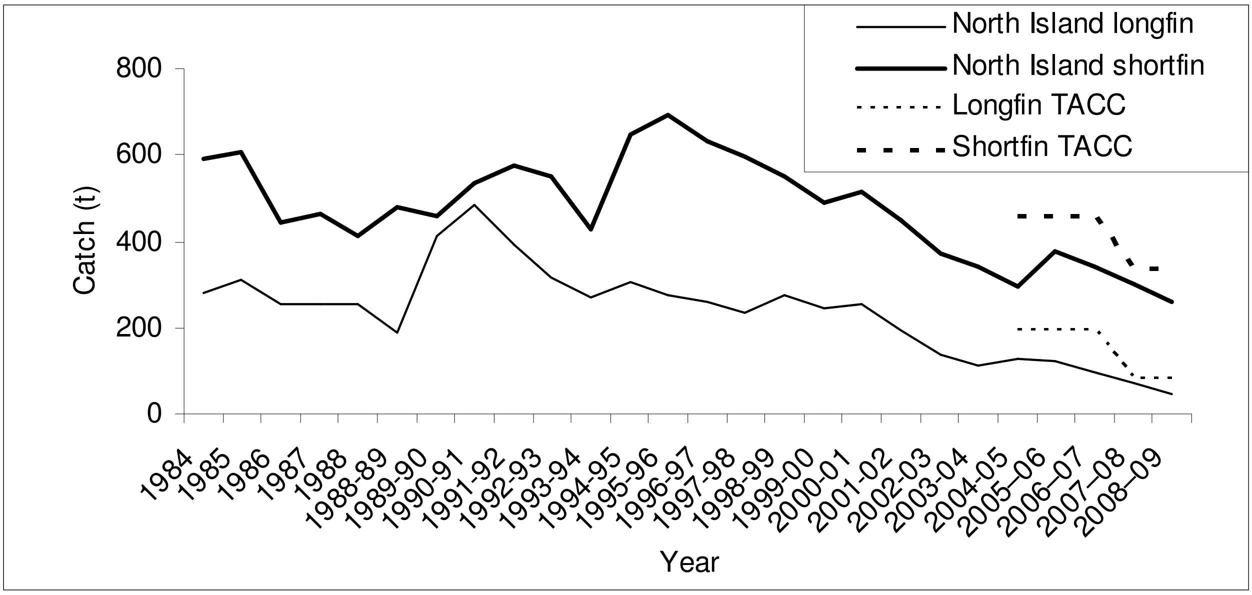


Figure 4-4: The New Zealand total commercial eel catch, 1965-2009. Data for 1965-1987 are by calendar year, thereafter by fishing year (1 October – 30 September).

The present South Island TAC is 539 t, of which the total allowable commercial catch (TACC) is 78%, 20% is available for customary fishing, and 2% for recreational fishing (Figure 4-5). The customary and recreational catches are not monitored (except for occasions when a kaitiaki authorises the taking of given quantity of eels for customary purposes of hui and tangi under customary fishing regulations). On average, just two-thirds of the TACC has been caught in any of the five years since it was established. For the North Island, the TAC is currently 885 t, of which 73% is the TACC, 14% is for customary fishing, 11% for recreational fishing, and the remaining 2% is in recognition of other (unspecified) sources of fishing-related mortality. The TACC for the North Island is separated by species, and in the 2004/05 fishing year (the only year of data since North Island eels were introduced into the quota system), only 65% of the TACC for shortfins (457 t) was taken, together with 67% of the TACC (193 t) for longfins. Much of this reduction is considered to be a consequence of industry rationalization associated with entry of eels into the QMS. Today, apart from National Parks, various reserves, and a few designated non-commercial areas, virtually all accessible waters have been fished commercially.

The regions represented by the Quota Management Areas (QMA's), and Eel Statistical Areas (ESA's) are given in Table 4-1. The catches by ESA (summed over the past 16 or 17 years), are given in Figures 4-7 (North Island) and 4-7 (South Island). Note that EEU represents eels not identified to species. For the North Island, the most productive areas are Waikato and Northland, with shortfin dominating catches in both areas. For the South Island, Te Waihora/Lake Ellesmere is the dominant area (virtually all shortfin), followed by Southland and Otago whose catches are dominated by longfins.



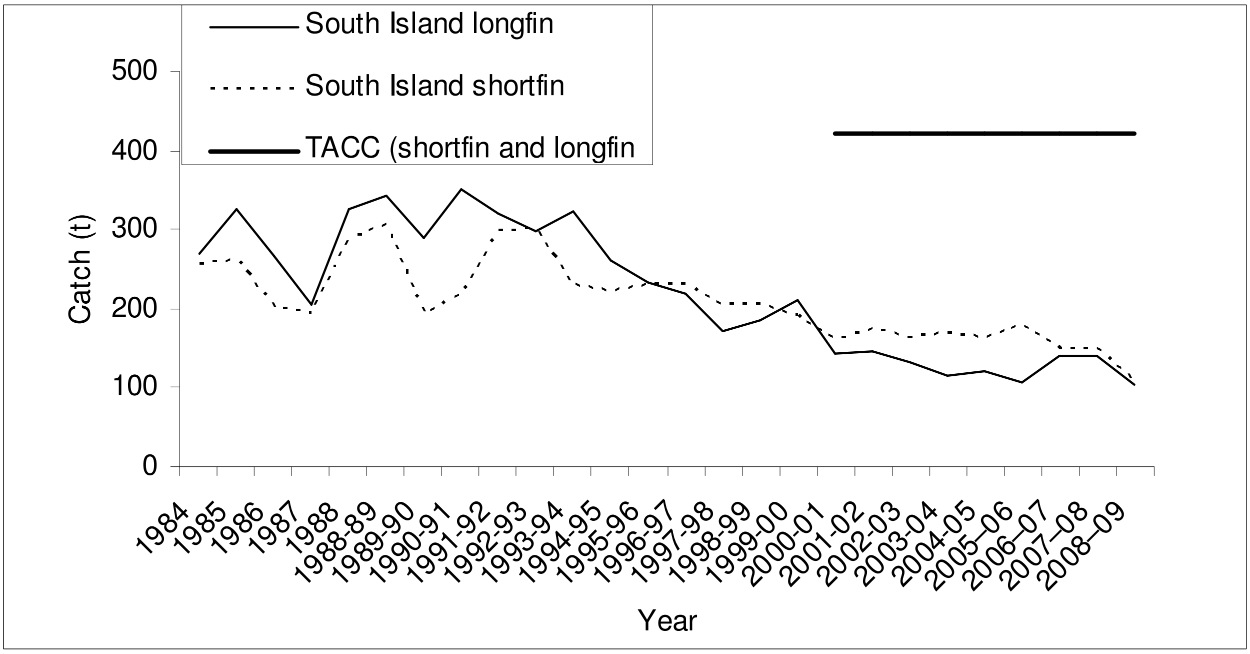


Figure 4-5: The North (upper) and South Island (lower) commercial eel catch, by species. Also shown is the TACC for each island. From Beentjes and Dunn (2010).

Table 4-1: Quota Management Areas (QMAs) for longfin (LFE) and shortfin (SFE) eels and both species combined (ANG), and eel statistical areas (ESA alpha codes) replaced numeric codes on 1 October 2001)

Area	QMA LFE	QMA SFE	ESA (alpha) (after 1 Oct 2001)	ESA (numeric) (before 1 Oct 2001)
Northland	LFE 20	SFE 20	AA	1
Auckland	LFE 20	SFE 20	AB	2
Hauraki	LFE 21	SFE 21	AC	3
Waikato	LFE 21	SFE 21	AD	4
Bay of Plenty	LFE 21	SFE 21	AE	5
Poverty Bay	LFE 21	SFE 21	AF	6
Hawke's Bay	LFE 22	SFE 22	AG	7
Rangitikei-Wanganui	LFE 23	SFE 23	AH	8
Taranaki	LFE 23	SFE 23	AJ	9
Manawatu	LFE 22	SFE 22	AK	10
Wairarapa	LFE 22	SFE 22	AL	11
Wellington	LFE 22	SFE 22	AM	12
Nelson	ANG 11	ANG 11	AN	13
Marlborough	ANG 11	ANG 11	AP	14
South Marlborough	ANG 12	ANG12	AQ	14
Westland	ANG 16	ANG 16	AX	15
North Canterbury	ANG 12	ANG 12	AR	16
South Canterbury	ANG 14	ANG 14	AT	17
Waitaki	ANG 14	ANG 14	AU	18
Otago	ANG 15	ANG 15	AV	19
Southland	ANG 15	ANG 15	AW	20
Te Waihora (outside Migration Area)	ANG 13	ANG 13	AS1	21
Te Waihora Migration Area	ANG 13	ANG 13	AS2	21
Chatham Islands	LFE 17	SFE 17	AZ	22
Stewart Island	ANG 15	ANG 15	AY	23

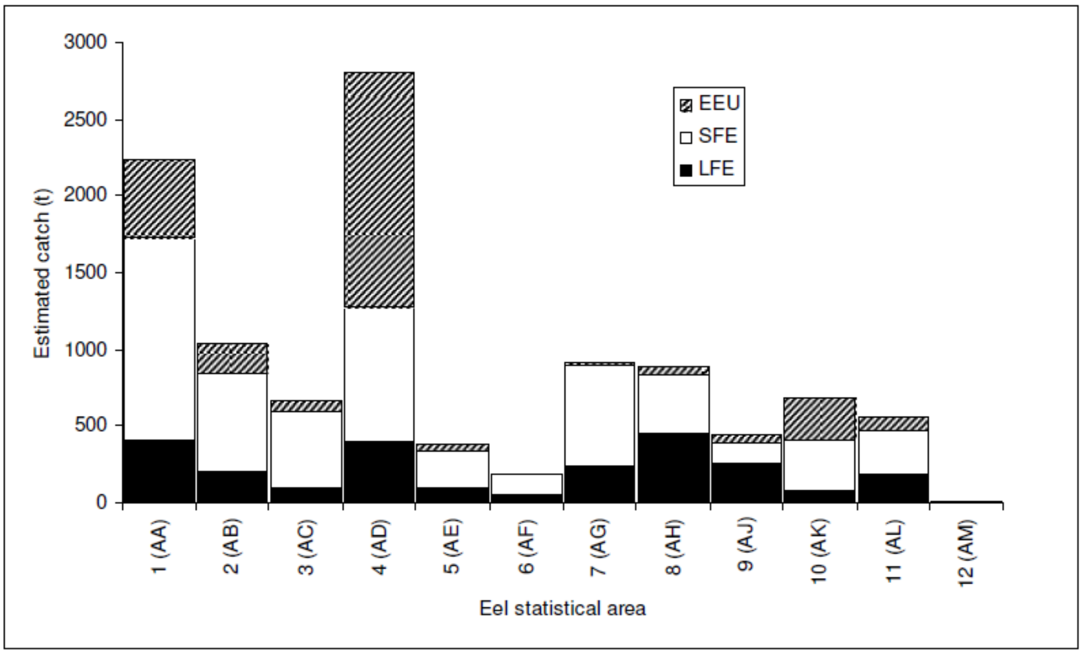


Figure 4-6: North Island estimated commercial catch of eels by area (ESA), 1990/91 - 2006/07. See Table 4-1 for ESA codes. Data from Beentjes and Dunn (2010).

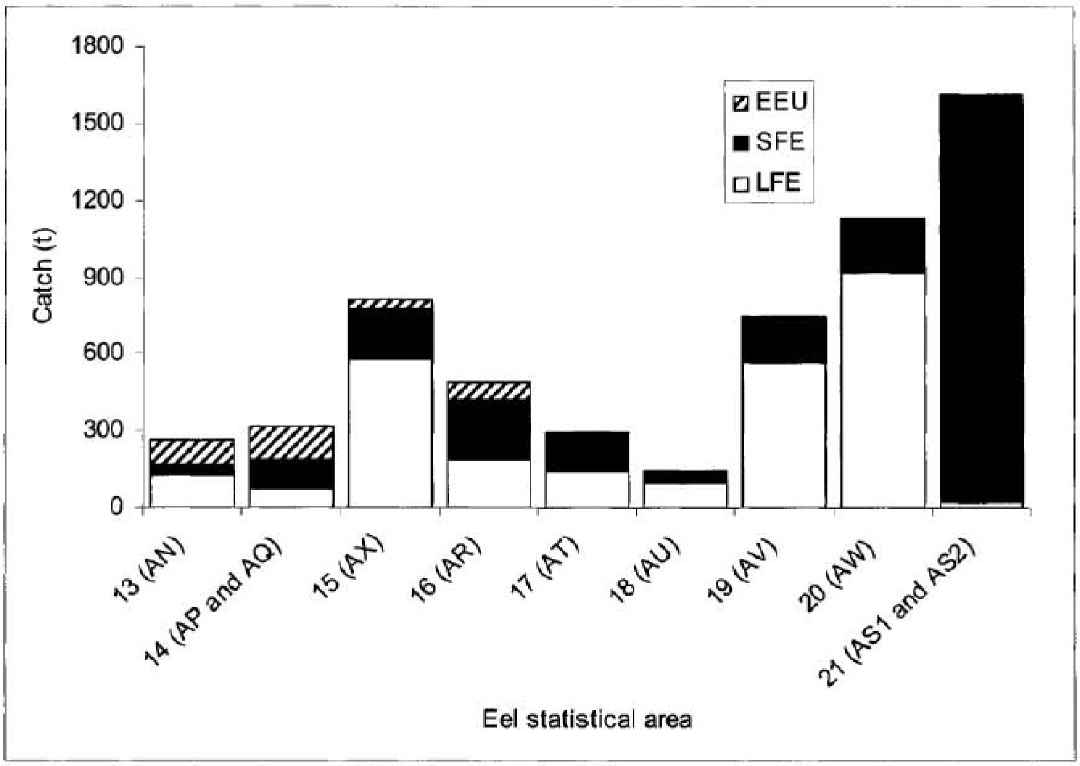


Figure 4-7: South Island estimated commercial catch of eels by area (ESA), 1990/91 - 2005/06. See Table 4-1 for ESA codes. Data from Beentjes and Dunn (2008).

Apart from small quantities of glass eels that can be caught for research purposes, it is not legal in New Zealand to catch or export glass eels. High overseas prices for glass eels in the 1970's stimulated experimental capture of this life stage in the Waikato River, the river with New Zealand's largest recruitment. As much as 6 t was caught in a single year (Jellyman, 1979), although anecdotal reports indicate that such large recruitment is now infrequent. Apart from an experimental eel farm in the north of North Island (Whangarei), there is currently no intensive farming in New Zealand; trials of eel fattening (short-term, low density) showed some promise, but the economics of the operation were uncertain (Chisnall and Martin, 2002a, 2002b).

With the exception of Te Waihora/ Lake Ellesmere, there are no targeted fisheries for silver eels in New Zealand. This is not because of legislation, but largely because New Zealand rivers are subject to considerable variability in flow, making capture of silver eels very difficult during the periods of increased flow when most migrate (Todd, 1981; Boubée et al., 2001; Boubée and Williams, 2006). However, a voluntary ban on the taking of migrating eels has been self-imposed by commercial fishers in recognition that adequate escapement of adult eels is critical to the sustainability of stocks. Male shortfin silver eels usually constitute two-thirds of the commercial catch of the Te Waihora/Lake Ellesmere fishery, because there is evidence that managing this fishery in favour of larger shortfin females is a worthwhile management strategy (Jellyman and Todd, 1998; Jellyman, 2001).

Despite the heavy exploitation, there is little evidence that shortfins are declining nationally (Beentjes and Bull, 2002; Jellyman, 2009). As shortfin males seldom exceed the minimum commercial size of 220 g, the commercial fishery is effectively for females only (with the exception of the fishery for male silver eels in Te Waihora/ Lake Ellesmere, where the size restriction is relaxed).

Although there used to be various types of fishing gear used to catch eels (nets, pots, spears), today the only significant method for commercial harvest is fyke nets. These are hoop nets and come in a range of shapes and sizes – the most common type has a single wing with two internal valves (or throats). Double-wing nets are sometimes used. Nets set to target longfin are usually baited whereas nets for shortfin aren't baited but set in likely areas (backwaters, slow-flowing reaches, lake margins during floods, etc.).

Earlier regulations included a prohibition on setting of fyke nets where flow exceeded 0.2 m/s. Like most regulations of that time, it was designed to minimise the bycatch of trout rather than benefit catches of eels. Likewise, mesh size could not be less than 12 mm, on the basis that this would enable escapement of undersized eels (then 150 g). Two escapement tubes were required to be fitted to each net. From 1993/94, the minimum commercial size of eel everywhere except in Te Waihora/Lake Ellesmere, was increased to 220 g, and the size of escapement tubes increased accordingly to 25 mm internal diameter. A minimum size of 140 g was introduced to Te Waihora/Lake Ellesmere at that time, with increments of 10 g per year to bring the lake up to the national minimum size within eight years. Subsequently, changes were made to the mesh size of nets as it was recognized that escapement tubes prevented retention of most under-sized eels, and finer mesh resulted in less damage to eels (as captive eels poke their snouts through the net, the skin would become eroded, and fungus disease would eventuate).

Fyke nets are highly efficient, and research has indicated that baited nets can consistently remove more than half the longfins in a waterway within a single night's fishing (Jellyman and Graynoth, 2005). Also, being ecologically dominant, large longfins are more vulnerable to capture than smaller longfins. A number of reviews and research programmes have highlighted the vulnerability of longfins, and the need to implement more conservative management practices to avoid substantial reductions in this fishery (Chisnall and Hicks 1993; Jellyman et al., 2000; Hoyle and Jellyman, 2002; McCleave and Jellyman 2004; Jellyman, 2009). A 4 kg upper size limit, in place in the South Island since November 1995, was recently (March 2007) extended to include the North Island. Although this provides protection for large longfins, modelling has indicated that the probability of capture before this size is attained is very high (Hoyle and Jellyman, 2002).

5 Factors impacting eel stocks

The freshwater life stages of freshwater eels are vulnerable to a number of anthropogenic impacts, with the most noticeable being loss of habitat, denial of access to habitats, direct mortality impacts via hydro turbines, pumping stations etc, and possible over-exploitation. In addition, eel stocks are subject to the vagaries of disease, reduced water quality and quantity, and natural variability in recruitment.

While there are a number of diseases that eels contract in freshwater, to date none of these have been of epidemic proportions, and any mortalities tend to have been small and localised. Fortunately New Zealand is free from the swimbladder nematode *Anguillicola crassus* that has decimated some European, North American and Japanese stocks, and may inhibit the ability of eels to spawn (e.g. Palstra et al 2007).

In response to growing concerns about the longterm sustainability of harvest levels, especially of longfins, fishery managers have taken deliberate actions to reduce catches, including changes in the minimum size, an increase in reserve areas, removal of part-time fishers, a moratorium of fishing licences, and reductions in TACC's. The eel industry itself has also taken some responsibility for self-regulation through voluntary prohibitions on taking migratory eels, a general raising of the minimum size (from 220 to 300 g), and often not targeting capture of longfins. In addition, the nature of the commercial fishery has changed somewhat, with much of the North Island fishery carried out in farm ponds and small lakes, where regular fishers are able to enter into access agreements with landowners, and as this gives them some certainty of access, they are able to rotationally fish such areas.

5.1 Habitat loss

Being a somewhat lowland species, shortfins have been particularly affected by drainage of wetlands and channelization of rivers. It is estimated that wetlands that covered at least 670,000 ha before European settlement have now been reduced to about 100,000 ha (Ministry for the Environment 1997). Within the Waikato Catchment, the most productive eel-fishing region, the loss of wetlands was estimated to be 84% between 1840 and 1976 (McDowall 1990). Much of this drainage pre-dated the commencement of commercial eel fishing but nonetheless resulted in a huge loss of habitat for shortfins. Shortfins are also the species that responds most to flooding and feeds extensively in newly inundated areas (Jellyman 1989; Chisnall and Hayes 1991), and channelization of waterways has reduced such feeding opportunities (Chisnall 1989). The biomass of larger eels is directly related to the amount of suitable cover (Burnet 1952), so the loss of cover by such practices as macrophyte removal and channelization of waterways, together with siltation, reduces the quality of habitat available to both species.

There has also been a substantial loss of forest, both pre- and post-European settlement; for example, over the past 200 years, forests have been reduced from 53% of land area to 23%, with a corresponding increase in grassland from 30 to 50% (Ministry for the Environment 1997). Ironically, conversion to pasture may have benefited eels, especially shortfins, since higher densities occur in pastoral streams than in either native or exotic forest streams (Hicks and McCaughan 1997).

Much of the low-lying land in New Zealand requires drainage to be used for pastoral purposes. Beentjes et al. (2005) collated information on the extent of drain cleaning practices throughout New Zealand; the total estimated length of waterways cleaned in New Zealand each year is about 15 500 km, most of which (66%) are drains, followed by stockwater races and natural waterways (12 %). Just three councils carry out nearly half the total length of waterways cleaned in New Zealand: Environment Waikato (22%), Selwyn District Council (16%), and Environment Southland (11%). The frequency with which waterways are cleaned is highly variable, ranging from several times per year to every 10 years, or as required, and most common methods used are herbicide spray and mechanical excavation. Less common methods include hand-cutting weeds and mechanical cutting using weed-boats. The total cost to New Zealand Regional and District Councils to maintain waterways is about $5.8 million.

Studies show that periodic drain clearance creates a highly variable and unstable environment, which is poor habitat for many of our native fish species, but eels appear to be less adversely impacted and may flourish if there is ample cover. There are few published studies in New Zealand that have attempted to quantify or document the effects of mechanical or chemical drain cleaning on mortality of eels and the results are inconclusive, but anecdotal information indicates that eels are frequently scooped out of drains by mechanical excavators and dumped on the bank side where they die if they are unable to return to the watercourse.

In addition to drain clearance, there are many pumped drains throughout New Zealand. Many of these are likely to have only coarse “trash-rack” screening, meaning migrating eels could enter. There have been no studies on the extent of such entry of eels, nor on the extent of morality associated with different types of pumps. The issue of drain mortality will be more an issue for shortfin eels than longfins, but again there are no data to back up this supposition.

5.2 Hydro impacts

Since longfins are the species that penetrate farthest inland, the installation of hydro dams has impacted this species the most by compromising their upstream access. Thus almost 10% and 22% of the total area of North and South Island catchments, respectively, are affected by hydro, with attendant problems for recruitment of juvenile eels and escapement of silver eels.

At the time Roxburgh Dam was being built on the Clutha River in the 1950’s, the advice from the fishery managers was that no fish pass was necessary (Jellyman 1984), apparently to “protect upper lake fisheries from contamination by eels or salmon“. Lack of recognition of the importance of eels mean that they were effectively excluded from access beyond all hydro dams, although small numbers managed to climb over dams like Karapiro (Jellyman 1977). The first organised upstream transfers of juvenile eels commenced at Matahina Dam (Rangitaiki River) in 1983 (Beentjes et al. 1997) by the Wildlife Service (now DoC), and this was followed in 1984 at Patea Dam, and at Karapiro Dam on the Waikato River in 1992. Since then, all significant hydro dams that impede upstream eel passage have progressively implemented an upstream passage programme. The major exception is Roxburgh Dam, the only major river system where there is no annual monitoring of elvers (although an elver passage facility was installed in 1996, there has been no agreement reached between Contact Energy and the local iwi about monitoring this, hence it has not operated since 2004).

Ensuring downstream passage of silver eels past dams is much more difficult and problematic. As most migrations of maturing (silver) eels occur during periods of increased flow, there is some likelihood of downstream passage occurring if spillways are operating; overtopping spillways can often provide suitable passage conditions provided there are no velocity-absorbing devices at the base of the spillway ("dragons teeth" etc). In the case of the Patea Dam, the bottom opening gates are opened for an hour after sunset following a period of significant rainfall (Watene and Boubée 2005), or when the dam operators notice an accumulation of migrating eels above the power station.

If passage through turbines occurs, there is a high chance of eels being killed – the probability of death depends on variables such as the size of the eel (the chances of a mechanical strike increases with increasing length of eel), speed of rotation, head of water, and type of turbine. Turbine mortality has been observed at Manapouri, Karapiro and Pātea Dams, but will occur at many others. There have been no specific studies of turbine mortality in New Zealand, but there are generic relationships that can be used to estimate the chance of eels of varying lengths surviving entry (e.g. Larinier and Travade 2002). A review of fish passage through turbines in New Zealand concluded that survival of large migrating eels (over 800 mm in length) was likely to be nil (Mitchell and Boubée 1992) i.e. effectively all longfin female eels entering turbines would be killed. Figure 5-1 shows estimated mortalities of eels for various hydro stations in New Zealand – the lower mortalities of Karapiro and Waipapa are due to different turbine types than the other stations.

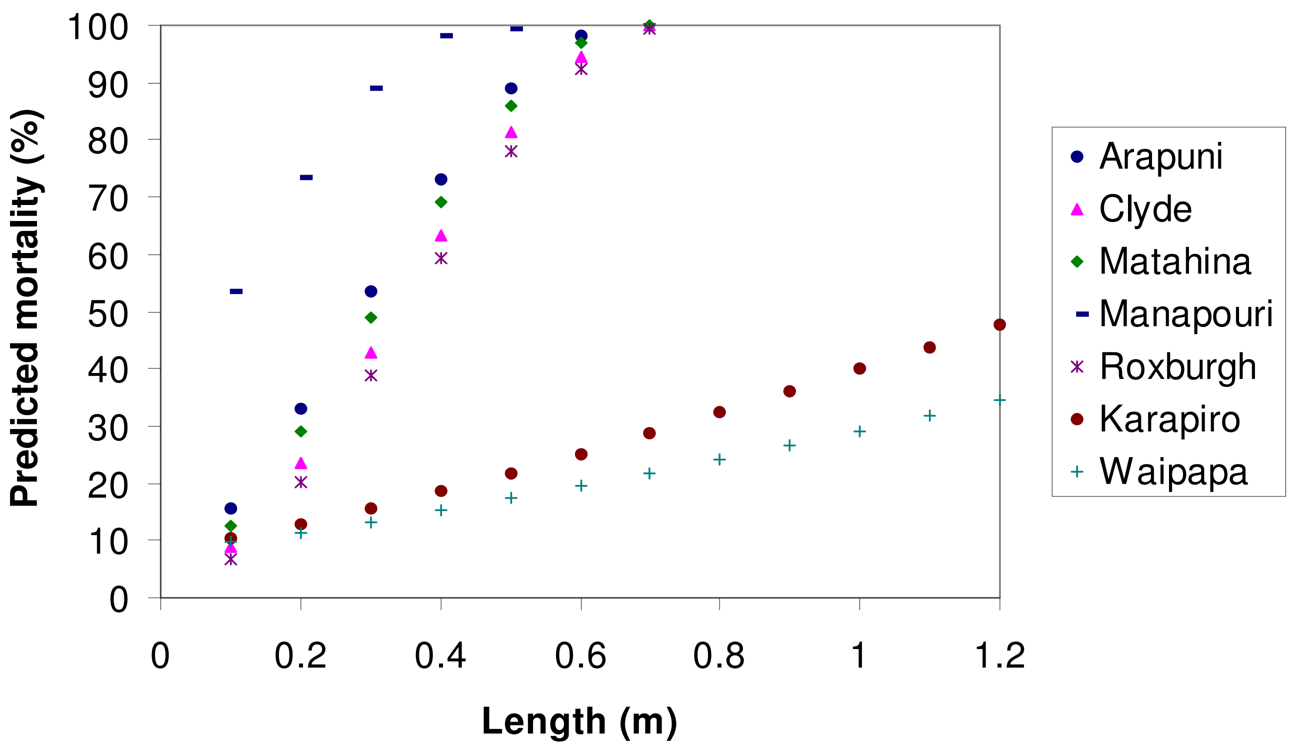


Figure 5-1: Estimated mortality of migrating eels of varying lengths, for the different hydro stations in New Zealand.

5.2.1 Estimation of the number of eels killed at hydro stations

Graynoth et al. (2008) reported that hydro dams have had relatively little effect on eel stocks in the North Island because natural waterfalls (e.g. Huka and Okere Falls) used to prevent eels from reaching Central North Island lakes and rivers. “Hydro dams have excluded eels from a short section of the Waikato River and its tributaries upstream of Karapiro and Arapuni (Hobbs 1948); from the upper Pātea River upstream of the Pātea Dam; and from the Rangitaiki River upstream of the Matahina Dam…… It is estimated that hydro dams have reduced access to waters in the North Island that would support about 460 tonnes of eels”. In contrast to the North Island, dam construction in the South Island has severely restricted eel access to many inland waters. Eels used to be found in most waters with the possible exception of the Rangitata River, upstream of the Rangitata Gorge, and several small and unproductive catchments upstream of waterfalls in South Westland and the Fiordland National Park. Graynoth et al. (2008) estimated that about 3900 tonnes of longfins could be supported in the upper reaches of the Waitaki, Clutha, Waiau, and other rivers impacted by hydro in the South Island, and another 2500 tonnes in natural lakes and hydro reservoirs. “If the major reservoirs are excluded (536 tonnes), then the total tonnage in rivers and lakes reduces to 5800 tonnes. Most of the habitat upstream of dams in both islands would have been dominated by longfin eels, so dams have reduced eel access to waters that could support about 6260 tonnes of longfin eels. This is equivalent to about 36% of the total original tonnage (habitat) of longfin eels from throughout New Zealand (17 384 tonnes)”.

The lakes and rivers above hydro dams are not devoid of eels, although recruitment to most is compromised. An estimated 40 t of longfin eels was harvested annually from the upper Clutha lakes for many years (Jellyman 1984), although this fishery has virtually disappeared as resident eels have been caught and no recruits have replaced them (apart from experimental transplants of small eels, Beentjes and Jellyman 2003). The Waikato hydro lakes contribute 10 - 25 t of commercial eels annually (Boubee and Jellyman 2009) as a result of upstream elver transfers.

There are no estimates of current stocks of adult eels within hydro lakes. In reality, this would be a very difficult exercise as there are varying degrees of natural and enhanced recruitment at different dams. Starting from the estimated potential production of 6260 t of longfin from hydro-affected waterways (Graynoth et al. 2008), a conservative “guess” might be that these waters now hold only 10% of that original biomass, say 600 t. Using data from a longfin eel population model (Bonnett et al. 2007), then 600 t of longfin would comprise approximately 282 t of male eels and 318 t of females (at an average weight for yellow (immature) male eels of 0.332 kg, this equates to 849,400 yellow males; equivalent figures for females at an average weight of 1.852 kg is 171,700 yellow female eels. Again using this population model, on average, ~ 2.7 % male and ~ 2.3 % female yellow eels become migratory each year, meaning that these quantities of male and female yellow eels would produce an average of 22,920 mature males and 3950 mature females per annum. These males would weigh about 51.9 t and the females 14.0 t, for a total of say, 66 t.

Over the past 5 years, the average annual commercial catch of longfin eels has been approximately 220 t per year. Therefore, assuming that the hydro lakes and rivers upstream now contain only 10% of their former (pre-hydro) biomass, and that 100% of migratory eels are killed during turbine passage (an acknowledged over-exaggeration), then hydro mortality could be equivalent to 30% of the total commercial longfin catch, or 9% of the total commercial eel catch (both species). Of course, if the hydro stock is only 5% of the former stock, then this would reduce these estimates proportionately to 15% and 5% respectively.

Beentjes (2011) gives estimates of the mean number of eels of each species processed during the 2007/08 and 2008/09 fishing years. Using these data, it is possible to express the estimated hydro mortality in terms of approximate numbers of eels killed. Using Beentjes (loc. cit.) mean species weights for each year, the total quantity of longfins harvested in 2007/08 would be approximately 383 100, compared with 876 900 shortfin. Equivalent figures for 2008/09 are 187 000 longfin and 723 100 shortfin. The above estimated numbers of longfin migratory eels that might be killed at hydro stations (n = 26 870) would be 7% and 14% respectively of the 2007/08 and 2008/09 total NZ longfin catch.

So, although we are lacking estimates of the quantities of eels presently within the hydro lakes, these projections indicate that the present commercial harvest of longfin eels significantly exceeds the estimated numbers of migrants that could be killed annually by hydro turbines. Using an average figure of 10% for the estimate of eels killed at hydro stations as a percentage of annual harvest, then the turbine mortality would need to be 10 times the estimate to equate to the commercial harvest.

6 Indicators of stock well-being

6.1 Recruitment indices

Monitoring eel recruitment is an essential component of understanding the well-being of stocks. Until glass eels are able to be produced in the laboratory in quantities approaching wild recruitment (and at competitive prices), the wild eel fishery and eel culture industries worldwide will be dependent upon wild recruitment. Significant reduction in recruitment is arguably the most compelling indicator that stocks are under pressure, whether that be anthropogenic or from natural causes like disease. Hence, having some long term measure of recruitment is regarded as essential to responsible monitoring of stocks.

The most sensitive measure of recruitment is to monitor glass eels, the stage of arrival from the sea. For northern hemisphere eel species, this is possible by obtaining statistics from commercial glass eel fisheries. In the absence of such fisheries, New Zealand fishery managers have opted to monitor elvers (small eels of mixed cohorts, that migrate upstream during successive summers). However, there has also been some effort to establish a glass eel recruitment database.

6.1.1 Glass eels

Glass eels are the end product of a 5000 km migration by adults, the act of spawning itself, and the uncertainties of a 6-month larval life at sea. Numbers of glass eels arriving at river mouths are subject to considerable year-to-year variation – for instance, when the viability of establishing a glass eel fishery in the lower Waikato River was investigated in the 1970's, numbers of glass eels caught in consecutive years varied by a factor of 10 (Jellyman 1979).

There is no "rule" about the length of time that recruitment time-series need to be to be meaningful, except that "longer is better", and preferably the number of years should exceed the generation time of the species – for longfins, such a time series would exceed 30 years. For *A. anguilla,* there are records from commercial glass eel fisheries going back 100 years (Dekker 2003) and these provide a robust source of material to track the severe reduction in recruitment across the geographic range of the species.

As part of a Public Good Science Fund (PGSF) research programme on eels, NIWA commenced regular sampling for glass eels, initially at 12 sites around New Zealand, although these were subsequently reduced to 6 sites. Details of sampling are contained in Jellyman et al. (1999), but in brief, sampling was by electric fishing the lowermost riffle at a given site during low tide. All glass eels caught were counted, and a sample of ~ 100 returned to the laboratory for identifying by species, classifying by pigmentation (a measure of their duration in freshwater), measuring and weighing. The total catch was adjusted by the species proportions in the sample, and densities of each species expressed as number/100m^2. Newly arrived glass eels were those that were in the early stages of pigmentation (5B - 6A23 of Strubberg 1913). Data were examined by region, with region being either North or South Island ("island effect") or East or West Coast ("coast effect"). For analysis, the density data were log transformed as they were not normally distributed. The data series ran from 1995 – 2006. While sampling in the early years ran for five months (August – December), this was subsequently reduced to the main months of September and October. Thus the following analysis for glass eel catches was for catches of newly arrived glass eels and all glass eels, sampled at 2-weekly intervals during September and October.

Newly arrived glass eels

There was a significant year effect for newly arrived shortfin glass eels (F = 5.728, P = 0.021) but not for longfins (F = 0.175, P = 0.192). The slope of the shortfin relationship was positive, indicating an overall increase on recruitment over the 12 year period of observation.

When the effects of the island and coast of collection were investigated using repeated measures ANOVA, results were very similar to those using the total glass eel samples.

Island effect: shortfins showed no island effect (F -= 0.178, P = 0.746) but a strong year effect (F = 4.365, P = 0.011), whereas longfins showed no effect of either of these factors (island, F = 0.197, F = 0.734; year, F = 2.783, year, F = 2.783, P = 0.052).

Coast effect: shortfin showed no coast effect (F = 0.572, P = 0.588) but a significant year effect (F = 3.244, P = 0.032), while longfins showed no relationship with either factor – coast, F = 88.557, P = 0.067; year, F = 1.620, P = 0.218).

All glass eels

Results were generally similar to those for newly arrived glass eels. Thus, over the 12 years of data, the densities of shortfins was significantly greater than longfins (F = 21.893, P < 0.001). A regression of the shortfin data for all sites showed that year had a significant effect (F = 5.475. P = 0.024), and that the slope of the regression was positive i.e. overall density of shortfin glass eels increased over time.

A similar regression for longfins showed no significant linear relationship (F = 2.443, P = 0.125), indicating no obvious trends in changes of density over time (although the slope of the least squares regression was slightly positive).

Repeated measures ANOVA showed that while there was no difference for shortfin recruitment between the North and South Islands (F = 0.127, P = 0.756), there was again a very strong effect of year (F = 5.120, P = < 0.001). When the effect of coast was analysed, there was no coast effect (F = 1.241, P = 0.381) but again there was a strong year effect (F = 5.310, P = < 0.001). These data confirmed that differences within the shortfin database were associated with the year-to-year variation in recruitment, and not the sampling location.

For longfins, repeated measures ANOVA found no differences between the two islands (island effect, F = 0.099, P = 0.783; year effect, F = 2.207, P = 0.055), but comparisons of densities on the two coasts showed that coast itself had a strong influence (F = 19.851, P = 0.047) with densities at west coast sites exceeding east coast sites, although year was not influential (F = 1.479, P = 0.209).

Waikato glass eels

The Waikato River has the largest known annual runs of glass eels. Historically, there are records of migrations that lasted for many hours – Cairns (1941) recorded a shoal that was 4.5 m wide and about 3.0 m deep, that took 8 hours to pass a point in the lower Waikato River. There are anecdotal reports of even larger migrations that ran for days.

During trials in the 1970's to ascertain the commercial potential of exporting live glass eels to Japan, fishing was carried out for 4 seasons. The quantities of glass eels caught over the 4 seasons varied by a factor of almost 10 (minimum 708 kg, maximum 6363 kg; Jellyman 1979). During research to determine environmental triggers of recruitment in the Waikato River in 2004 and 2005, Jellyman et al. (2009) were able to make some comparisons with the 1970's data and found;

- The proportion of longfins had declined from 12% to 3%.
- The main migration period seems to be several weeks earlier today than previously.
- Catch-per-unit-effort and duration of runs was significantly lower today than 30 years previously.

Collectively these changes were interpreted as indicating a reduction in overall recruitment to the Waikato River, especially for longfins.

Summary

Conclusions from this analysis of glass eel data were that:

- Shortfin glass eels were more abundant than longfins.
- For shortfins, recruitment varied significantly between years and showed an overall increase.
- There was no evidence that recruitment of longfins had declined over the period of record.
- Results for "newly arrived" glass eels were virtually identical to "all glass eels". The exception was that while freshly arrived longfin glass eels showed no differences between East or West Coast densities, the West Coast densities exceeded the East coast densities for all longfin glass eels.
- An obvious caveat for these analyses is that, relative to the generation times of the eels, the time frame of these data is very short. While it is encouraging that recruitment of longfin showed no decline over the 12 years, it would be premature to conclude that recruitment of longfins is stable.
- Yearly trends in both species were generally similar, indicating that both seemed to be responding to the same factors in the marine environment.
- In the river with the largest glass eel recruitment, the Waikato River, there is some evidence that present-day runs are smaller than 30 years previously, and the overall proportions, and hence numbers of longfins, has declined substantially.

6.1.2 Elvers at hydro dams

As the Ministry of Fisheries have recognised the importance of establishing an index of recruitment, they fund the annual collation of data on the number of elvers caught and transferred upstream at a series of hydro stations throughout New Zealand. The funding for such operations is provided by the respective hydro companies, and, in the case of the Waikato River, by a specific company (Eel Enhancement Company) formed to seed the upstream hydro lakes with juvenile eels.

The four main monitored sites are:

North Island: Karapiro Dam (Waikato River), Matahina Dam (Rangitaiki River); South Island: Arnold Dam (tributary of Grey River), Waitaki Dam (Waitaki River).

In addition, there are a number of supplementary sites that normally provide transfer data, especially Pātea Dam (Pātea River) and Mararoa Weir (Waiau River, Southland). There are a series of standardised protocols for monitoring, including provision of samples to determine average weight and species composition – these data enable the total number of elvers of each species to be estimated from bulk weights, at intervals during the migration season for each site. A critical factor to make the data comparable between years, is the use of the same trapping methods – historically these have changed at some sites, but changes are now few. However, it is important to recognise that the use of such unstandardised data can compromise analysis of longterm trends in recruitment. The most suitable data are listed in Tables 6-1 (shortfins) and 6-2 (longfins).

Table 6-1: Estimated numbers (1000s) of shortfin elvers trapped at elver recruitment monitoring sites by season (December-April) 1995-96 to 2010-11. Figures in italics are incomplete records.

Year	Karapiro Dam	Matahina Dam	Patea Dam	Piripaua Dam	Waitaki Dam	Mararoa Weir	Arnold River Dam
1995–96	822						
1996–97	974	10		2.1			
1997–98	*1529*	479					
1998–99	756			*2.7*		1.1	
1999–00	798			*2.5*			
2000–01	627			*5.4*			
2001–02	1351	592	707	3.7			
2002–03	1766	1360	372	10	0	0	
2003–04	1931	881	390	4.7	<0.1	0	
2004–05	1201	1102	-	7.7	0	0	20.4
2005–06	1695	965	*475*	2.6	0	0	6.2
2006–07	1117	326	*843*	3.8	0	0	55.2
2007–08	2027	2450	*759*	4.7	0	0	107.7
2008-09	1980	3791	399	7.3	*1.3*	0	96.2
2009-10	1476	924	290	7.3	0.3	0	15
2010-11	1260	-	227	9.3	0.5	0	64.6

Table 6-2: Estimated numbers (1000s) of longfin elvers trapped at elver recruitment monitoring sites by season (December-April) 1995-96 to 2010-11. Figures in italics are incomplete records.

Year	Karapiro Dam	Matahina Dam	Patea Dam	Piripaua Dam	Waitaki Dam	Mararoa Weir	Arnold River Dam
1995–96	333						
1996–97	246	4					
1997–98	*510*	136					
1998–99	341	-		*0.4*		43	
1999–00	94	-		*0.1*		90	
2000–01	155	-		*0.2*		28	
2001–02	246	27	48	0.4		-	
2002–03	176	124	8	0.2	0.1	36	
2003–04	200	64	1	*0.2*	4.6	98	
2004–05	132	15	1	0.5	1.5	64	7.1
2005–06	483	228	87	0.2	4.7	46	8.3
2006–07	179	160	53	0.4	3.3	118	51.9
2007–08	701	929	*98*	1.1	4.1	134	78.4
2008-09	298	517	82	2.2	*3.5*	81	86.9
2009-10	232	78	20	2.9	2.1	71	4.7
2010-11	175	84	20	2.5	2.4	198	49.2

Analysis of these data presents a number of problems. Firstly, as indicated, analysis assumes similar sampling effort between years – this was not always the case as changes were made to types and numbers of traps and also the locations of traps. The second issue is that the elvers arriving at dams are comprised of a number of different cohorts (year classes). For example, Karapiro elvers contain varying proportions of at least 3 age classes (Jellyman 1979); the proportions of these age classes will not be constant between years but will vary according to factors like overall flows, as higher flows are likely to encourage a higher proportion of younger eels to migrate upstream (Jellyman and Ryan 1983). Unfortunately, as the lengths of consecutive age classes overlap, it is not possible to estimate proportions of these age classes from size alone, meaning that ageing of individuals is required. This is not part of the contracted work by the Ministry of Fisheries.

The following data are for the main elver sites, plus two additional sites (Matahina Dam, and Mararoa Weir) that have reasonably longterm data sets. To simplify comparisons, data for each year (for a particular site) were converted to an index of within-year recruitment by dividing each value for that year by the overall mean value for all years. Plots of these data indicate that while both species show reasonable agreement with respect to high and low years, there are also some major differences. Thus for shortfins, 2007/08 was a strong summer (4/5 sites showing much better than average recruitment), and 2008/09 was similarly good. For longfins, recruitment was also strong in 2007/08, and also in 2008/09 to a lesser extent. Shortfins recorded reasonably low recruitment in the late 1990's (1988-89, 1999-00, 2000-01), while longfins showed a somewhat similar trend of low recruitment in the late 1990’s, but also in 2002/03 and 2003/04 (Figure 6-1).

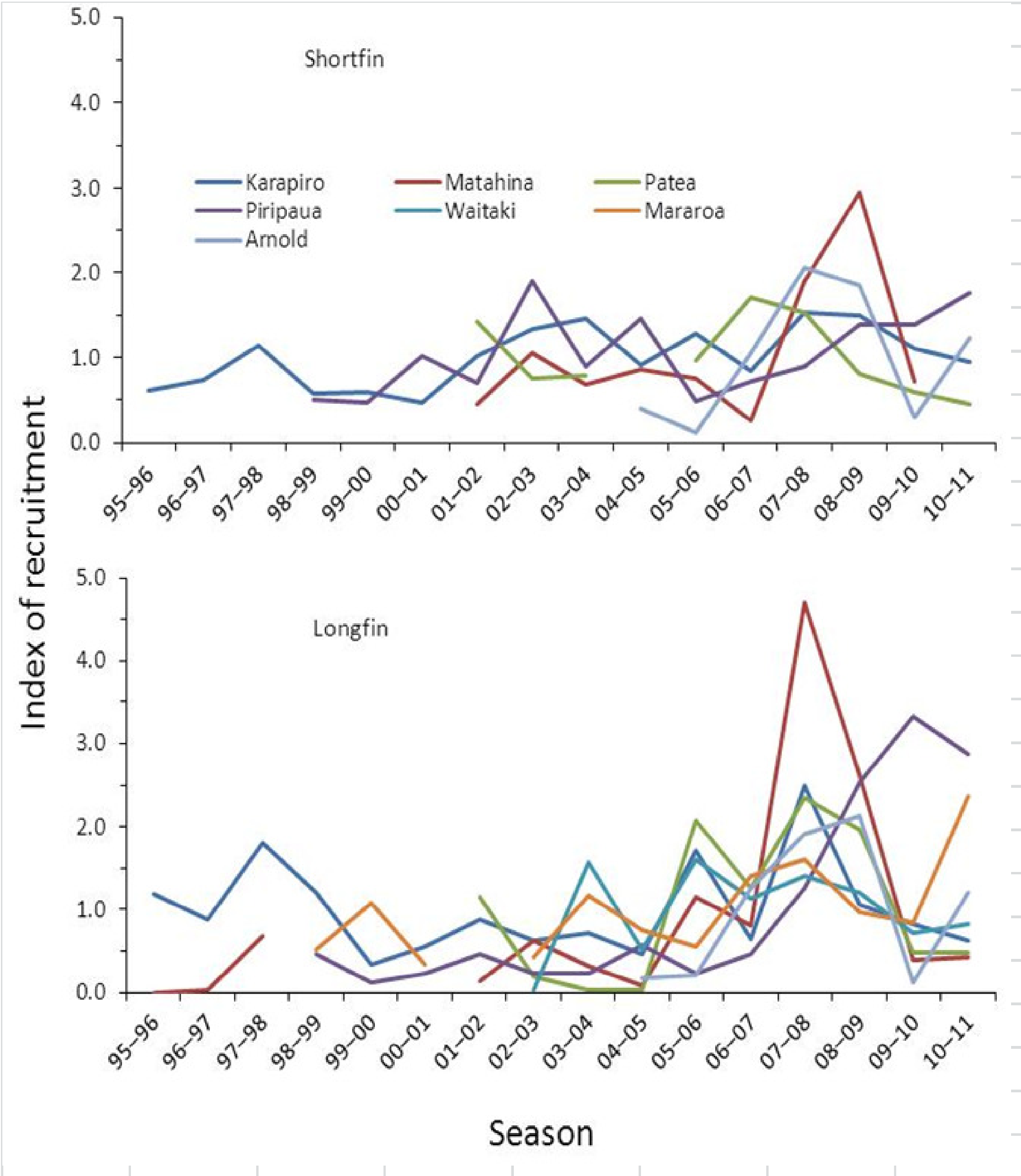


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Figure 6-1: Recruitment indices of shortfin and longfin elvers from hydro stations throughout New Zealand

Although the time-series are relatively short, each site was analysed to see whether there were indications of any trends in abundance over time. To enable comparisons of all data for each species, the % catch per year for each site were calculated. These % data were also used for each site to study in recruitment (linear regression) – in instances where outliers indicated the data were not normally distributed, a $\log_{10}$ transformation was used to reduce the influence of these data.

Combining all data showed that there were significant effects due to both species (ANCOVA: $F = 19.94$, $P < 0.001$) and year ($F = 21.38$, $P < 0.001$) – the abundance of shortfins was significantly greater than abundance of longfins. Thereafter, species were analysed separately, and the effect of year was examined by regression to look for any indications of whether there were significant changes over the period of record. Results (Table 6-3) showed that relationships at most sites were not significant ($P < 0.05$) meaning that relationships should not be used in any predictive way. Sites where there was evidence of an increase in elvers over time were Karapiro (shortfins), Piripaua (both species), and Mararoa (longfins). Even though the remaining relationships were not significant, it is informative to look at the slopes of the graphs of elver abundance over time; these slopes (Table 6-3) indicate a strong trend to increased abundance of both species.

Table 6-3: Results of linear regression analysis of the numbers of elvers per year recorded by species at monitoring sites. "Slope" refers to the slope of the graph that provided the best fit to the data = + indicates a net increase in the abundance of elvers over time, 0 indicates no difference (a slope of 0), and - indicates a net decrease. Log numbers refers to where the number was log transformed. Significant relationships are shown in bold.

Site	Years	Species	Slope	Numbers		Log numbers	
				R^2	P	R^2	P
Karapiro	16	Shortfin	+	**0.31**	**0.03**		
	16	Longfin	0	0.00	0.97	0.00	0.95
Matahina	10	Shortfin	+	0.26	0.14	0.24	0.15
	11	Longfin	+	0.01	0.36	0.09	0.38
Patea	9	Shortfin	-	0.11	0.38		
	10	Longfin	+	0.06	0.50		
Piripaua	14	Shortfin	+	**0.34**	**0.03**		
	13	Longfin	+	**0.64**	**0.001**		
Waitaki	Nil	Shortfin					
	9	Longfin	+	0.02	0.70	0.18	0.26
Mararoa	Nil	Shortfin					
	12	Longfin	+	**0.38**	**0.03**	0.39	**0.03**
Arnold	7	Shortfin	+	0.14	0.42		
	7	Longfin	+	0.12	0.45	0.10	0.49

As indicated, there are some concerns about the quality of these data, and the most reliable (and longest time series) comes from Karapiro Dam. For this site, the trend for shortfin is towards a significant increase over time, while for longfins the data show no significant linear trend, and the best fit of a straight line to the data indicated consistent recruitment over time. However, these data are strongly influenced by the occasional year of very large recruitment – for instance, if the data for 2007/08 are removed from the Karapiro dataset, the resulting regression for longfins has a negative slope (although it is still not statistically significant, $R^2 = 0.05$, $P = 0.42$)

Of concern is the relatively small number of elvers arriving at some sites. For the past 9 seasons, Karapiro and Matahina Dams have received an average of 286 000 and 244 000 longfins per annum, while Pātea has received 41 000. Of particular concern are the very low numbers that arrive at Waitaki Dam (~ 3 000 per year). When expressed as elvers per m^3/s (to give some relativity in relation to size of rivers to the numbers), the Waitaki numbers are minimal, but are in keeping with low recruitment to the East Coast of the South Island (see also 6.1.3). The only other sampling site in this region was the Roxburgh Dam on the Clutha River, but this site has not operated since 2003/04, and unfortunately, there are only six years of data (1996/97 – 1998/99, 2000/01 – 2003/04). However, here also the catches were very low, with a mean catch of 3533 longfin per year (no shortfins). Using a mean flow of 570 m^3/s, this equates to only 6 elvers/m^3/s, a very concerning statistic. Even if the Roxburgh trap was very inefficient and caught only 10% of the elvers, a recruitment of 35 000 longfin elvers for New Zealand's largest river is alarming. (Note that this is not the total recruitment to the catchment as Roxburgh Dam is about 120 km inland and while it has few tributaries downstream of Roxburgh, there is a significant resident eel population downstream of the dam). Given that the Roxburgh figures will underestimate the total number of recruits to the Clutha River, it still might be expected that recruitment figures would be somewhat similar to those at Karapiro, which is slightly further inland (150 km); however, the Roxburgh figure (3 500 longfins per year) is only 1% of the number of longfin arriving annually at Karapiro. However, even these numbers are not excessive compared with the annual recruitment from a small lowland lake measured from 1974 – 1978 (Lake Pounui) where annual elver recruitment ranged from 6700 – 190 000 (Jellyman and Ryan 1983; Table 6-4).

Table 6-4: The mean number of longfin elvers recorded at various sites, 2002/03 - 2010/11, expressed in relation to mean flows. For the Waiau River, * indicates the residual flow down the river channel, while the figures in brackets are the full catchment flows.

Site	River	Mean flow (m^3/s)	Mean number of longfin elvers	Mean number of shortfin elvers	Longfin elvers/ m^3/s	Shortfin elvers/ m^3/s
Karapiro	Waikato	327	286 000	1 616 000	875	4942
Matahina	Rangitaiki	74	244 000	1 376 000	3302	18595
Patea	Patea	26	41 000	529 000	1581	20346
Waitaki	Waitaki	367	3 000	0	10	0
Mararoa	Waiau	55* (437)	94 000	0	1709 (215)	0
Arnold	Arnold	50	41 000	50 000	819	1000
Lake Pounui	Lake Wairarapa	~2	560	85 000	280	42 500

6.1.3 Juvenile eels

Over the past 15 years, NIWA staff have carried out a number of electric fishing surveys on a range of waterways to investigate eel numbers and biomass. Some surveys focused on eel numbers, while others were designed to determine microhabitat requirements. For these surveys, a range of habitats were fished, and all eels caught were identified and measured. Thus these data provide snapshots of the size distribution of eels at a range of sites. The primary data are given in Appendix Table I.

Figure 6-2 gives the length distributions of juvenile eels from 2 large North Island catchments. While the shortfin show a near-normal distribution (heavily skewed to the left, indicating a high proportion of juvenile eels, and decreasing numbers of larger eels), distributions of longfin are quite different, indicating relatively low numbers of eels < 200 mm

(Ruamahanga) or their virtual absence (Whanganui). Similar scenarios can be repeated for many other catchments for which we have reasonable representative data from the lower and middle reaches of rivers. The most recent data (Figure 6-3; South Canterbury Rivers; Jellyman (2010) shows a marked lack of longfin < 300 mm – while some of this lack was attributed to periodic closure of the mouths of some of these rivers, the impact of such closures should equally affect stocks of shortfins, although this is less apparent from the data.

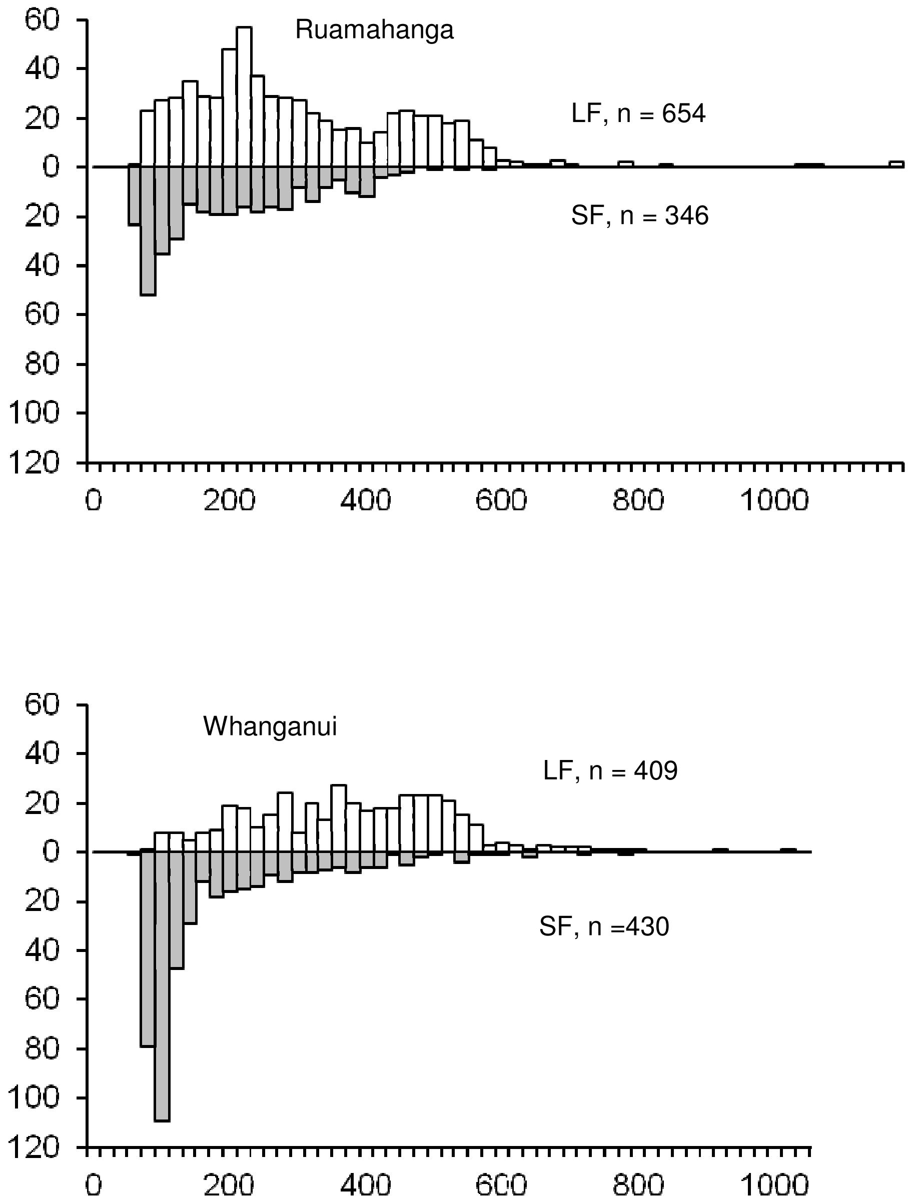


Figure 6-2:Length frequencies of juvenile eels electric fished from the Ruamahanga and Whanganui River and tributaries, 2005. The Y axis is the number of eels measured.

Similar trends are seen from South Island rivers. Figure 6-3 shows the length frequency distribution of both species of eel from a range of South Canterbury rivers (Orari, Opihi, Waihao), and again the lack of juvenile longfins is apparent.

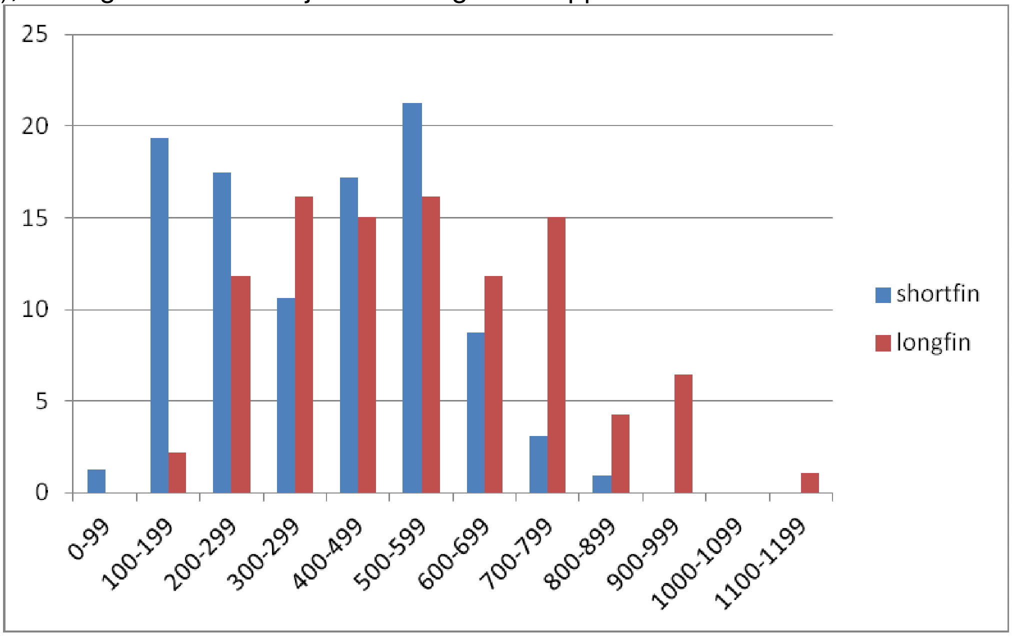


Figure 6-3: The length frequencies of juvenile eels electric fished from South Canterbury rivers, 2010.

When all data from studies listed in Appendix Table I are combined, the same trend towards low numbers of juvenile longfin is again seen (Figure 6-4). Numbers are large (shortfin n = 9659, longfin n = 10 644). Again, the lack of longfin in the smallest size class is of considerable concern, and indicative of poor recruitment. For example, 24 of the 28 sites where longfin were sampled had smaller numbers in the first length group (< 100 mm) than the next group (100-149 mm. Appendix Tables A-1 and A-2 include the percentages of eels in the first 2 size classes (<99 mm, and 100-149 mm) – for longfins, the overall percentages are 9% and 17% respectively, compared with 45% and 26% for all shortfins**.**

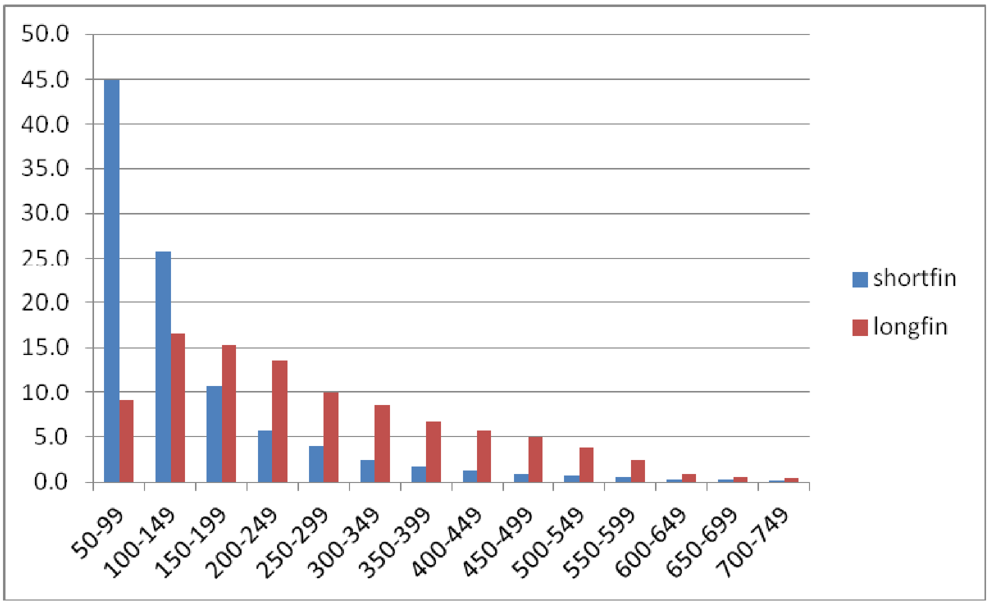


Figure 6-4: Length-frequency of both species of eel collected by electric fishing composite sample from sites throughout New Zealand; data in Appendix Tables A-I and A-2.

Given the random nature of much of this sampling, there is no reason to suspect that sampling was biased towards shortfin habitats, and/or neglected critical longfin habitats. Rather it is concluded that there is a disturbing lack of juvenile longfin eels. For longfins, all South Island sites and 7 of the 11 North Island sites showed a relative lack of the smallest size group.

6.1.4 Summary of recruitment indices

- There was no evidence from the glass eel database (1995 – 2006) of a decline in abundance of longfin glass eels over that period – however, it is noted that the time frame of these data is short relative to longfin generation times.
- From monitoring of elvers at dams, most sites showed no significant trends over the 7 – 16 years that data are available. Four of the 12 relationships were positively significant, and this included two relationships for longfins. However, the data are very "noisy" and strongly influenced by the occasional year of much better than average recruitment
- Numbers of longfins recruiting to the Waitaki and Clutha Rivers appear to be very low
- From electric fishing samples, there was clear evidence of an overall lack of juvenile longfins at sites in both islands. This was most pronounced for South Island sites.

6.2 Records on New Zealand Freshwater Fish Database

The New Zealand Freshwater Fish Database is a repository for records of freshwater fish collected by a variety of methods and individuals. Currently it contains over 31 000 records and has been the basis of many papers and reviews examining the distribution of fish in relation to a range of geographic and hydraulic variables. Because the species recorded are strongly influenced by the methods used, when collating data on the distribution and abundance of fish, it is advisable to filter the data by methods; the most commonly used method and also the one that provides most representative data, is electric fishing. While some records are quantitative, the common denominator is presence/absence of particular species. So, when these data are extracted (samples that have been electric fished, and where a species list is given), it is possible to examine the number of records of each species recorded over given periods of time – this is a measure of whether the occurrence of this species has changed over time. To check the validity of making comparisons over time and ensure there was no sampling bias for aspects like distance inland of sampling sites, comparisons of various site descriptors were made between years – none of the resulting comparisons showed any such bias, meaning that comparisons across time were valid.

The plot by year of the proportion of electric-fished sites that contained longfins (Figure 6-5) for the last 31 years shows a significant negative relationship (linear regression, $R^2 = 0.43$, $P < 0.001$) indicating a substantial decline in longfin abundance.

Other migratory species also show a decline in occurrence over recent years including torrentfish, bluegill bullies, redfin bullies, common bullies and lampreys. These data are collected New Zealand-wide and are an important index of species abundance. However, longfin eels show the most dramatic declines of any of the native fish species examined. Given the numerical strength of these data, and their collection from across the whole country, it is very unlikely that they represent some sampling bias against collection of diadromous species like longfins – accordingly the more likely conclusion is that they represent a real decline in the distribution and abundance of longfin eels.

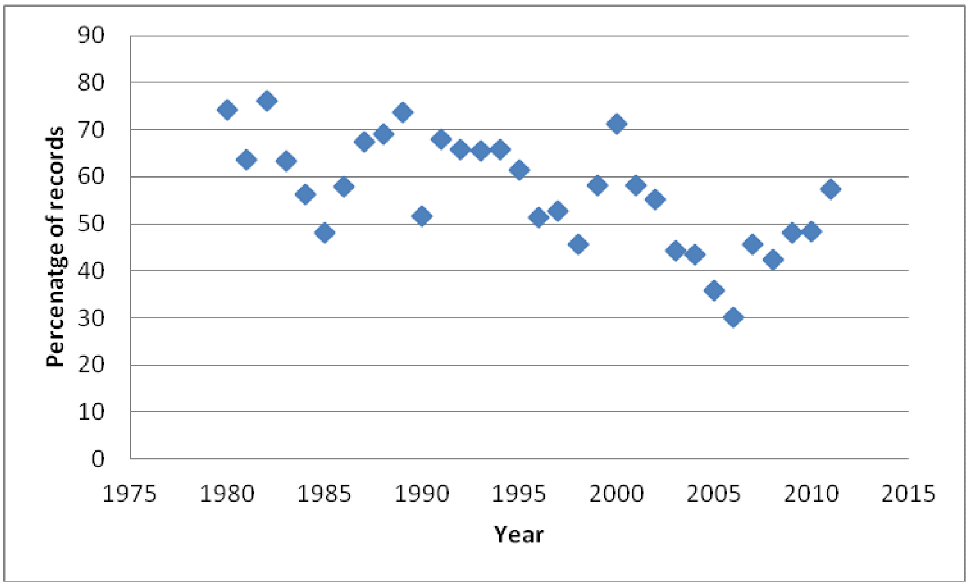


Figure 6-5: The proportion of FFDB electric fished records that contained longfin eels, 1980 – 2011.

When reviewing the status of freshwater fish in New Zealand, Allibone et al. (2010) expressed concern about the general decline in fish abundance and diversity over the four years since the previous assessment. In particular they noted that "For the longfin eel, where concern exists over the survival of females in freshwater (Jellyman 2009), the females that do reach the spawning area must encounter males and spawn. There is an unquantifiable level of risk that if the number of eels in the spawning migration declines to a critical level, then Allee effects (negative feedback factors such as in-breeding depression or inability to find suitable breeding partners that increase the rate of decline of a species; Allee et al. 1949) will drive reductions in spawning success and juvenile recruitment as eels fail to encounter other eels in the ocean".

6.3 Catch per unit (CPUE)

Indices of commercial catch are frequently used to assess the well-being of fisheries. One of the most common is catch-per-unit-effort (CPUE); for eels, this is usually expressed as kg of eels caught per net over a single nights fishing. Provided data can be standardised across time, analysis of trends in CPUE can be very meaningful indicators of trends in fish abundance. Care needs to be taken in the "grooming" of the data though, as, for instance, most fishers will become more efficient over time, and this can show as an increase in CPUE, even during a period when the fish stock itself might be diminishing (the collapse of the Grand Banks cod fishery in the North Atlantic is an often quoted example of this). Also, eel activity, and hence catchability, is affected by such factors as water temperature, lunar cycle, and water level (Jellyman 1979). Therefore, in examining CPUE trends, researchers have been careful to take such factors into account by producing standardised CPUE (Beentjes and Bull 2002). A further refinement is to select the long-term fishers from a region, and track their catches, as this avoids the variability that can be associated with new fishers entering the fishery (including those who might be employed for short periods by working on company licences).

The most recent review of CPUE for the South Island was for the period 1990 – 2006 (Beentjes and Dunn 2008). Data were extracted from the old Catch Effort Landing Return (CELR) system, which was replaced in 2001 with the Eel Catch Effort Return (ECER) and an Eel Catch Landing Return – this effectively removed the unidentified eel category (EEU), meaning eels were classed as either shortfin (SFE) or longfin (LFE). Data were analysed by Eel statistical areas (ESA's). The analysis captured 87% of the reported catch; half the reported catch was shortfin and half was longfin (60% of the shortfin catch was from Te Waihora (Lake Ellesmere).

ESA's had to be combined to provide sufficient data for analysis. For shortfins, there were sufficient data from 3 regions, with the possibility of 2 others, while for longfins, there were sufficient data for 4 regions (Table 6-5) – for longfins, these four areas comprised 63% of the total South Island longfin catch.

The trends in the 4 longfin areas are shown in Figure 6-6. The data for Te Waihora/Lake Ellesmere should be treated with caution, as fishers have operated a voluntary ban on landing of longfins in this lake for several years, and this will have the effect of artificially suppressing the longfin catch compared with earlier years. As stated by Beentjes and Dunn (2008), the CPUE data for Westland (ERA AX) show no overall trends, while those for Otago (AV) and Southland (AW) showed a decline until about 2000 and thereafter generally increased. They concluded "the analyses for the South Island ESA's where adequate data were available, indicated a general increase in CPUE for both longfin and shortfin eels since about 2000. For some areas this represented a reversal of the trend of declining CPUE apparent from previous South Island CPUE analyses based on earlier data. A possible reason for the change in trend may include the reduction in catch and effort (number of fisher's) resulting from the introduction of the South Island eel fishery into the QMS in 2000".

Table 6-5: Qualitative assessment of standarised CPUE indices for each species by ESA.

ESA	Region	% shortfin catch	% longfin catch	Sufficient data	
				SFE	LFE
13 AN	Nelson	0.8	4.4	No	No
14 AP and AQ	Marlborough	3.9	2.6	No	No
15 AX	Westland	7.0	22.2	?	Yes
16 AR	N Canterbury	8.0	6.1	?	No
17 AT	S Canterbury	4.6	3.9	No	No
18 AU	Waitaki	1.3	2.3	No	No
19 AT	Otago	5.8	21.3	Yes	Yes

20 AW	Southland	7.5	36.6	Yes	Yes
21 AS	Te Waihora/Lake Ellesmere	61.0	0.7	Yes	Yes

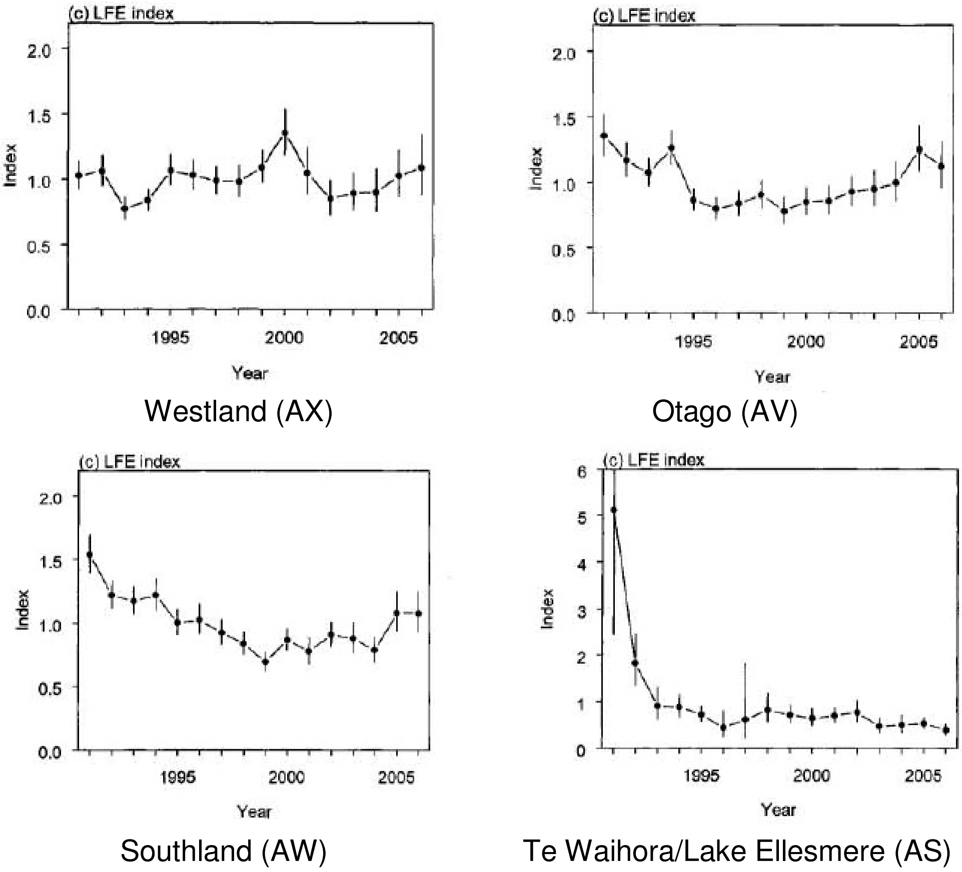


Figure 6-6: Standardised CPUE for longfins from South Island ESA's.

While the CPUE from Otago (ESA AV), and Southland (AW) to some extent, has increased over recent years, it should also be noted that the overall catch of longfin has declined over time, but again has been reasonably constant since 1994 (Southland) and 1997 (Otago) (Figure 6-7).

Trends in North Island CPUE for the years 1990 – 2007 were reviewed by Beentjes and Dunn (2010). Their conclusion was that " longfin showed trends of declining CPUE for all 10 areas analysed, and this decline was steep for Hauraki, and Hawke's Bay and moderate for all other areas except Waikato, where the decline was slight. Similar to shortfin, several indices exhibited a flattening of CPUE in recent years and in Taranaki a slight increase"; they noted that the flattening or slight increase occurred around the time of entry into the QMS in 2004-05 and might represent reduced catches and effort, and changes in core fishers associated with this (Figure 6-8).

Overall Conclusions: North Island: there is strong evidence of declines in CPUE in all ESA's, although some flattening of these trends in recent years. Of the three ERA's that contribute > 50% of the longfin catch (Rangitikei-Whanganui, 18.6%, Northland 17.3%, Waikato 17.2%), the Waikato shows a slight decline from historic levels (1991-1997), but has been very stable ever since – the other two areas show marked declines over the 17 years of record.

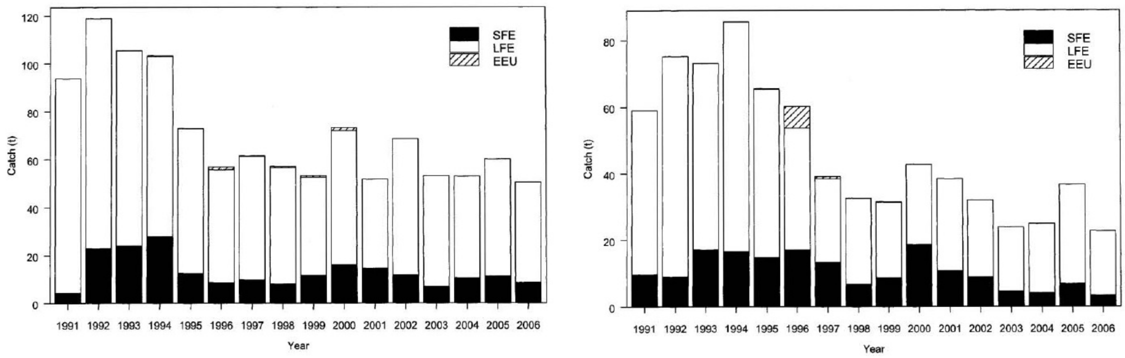
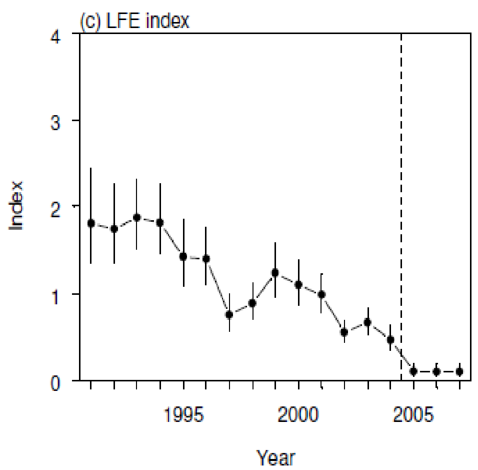
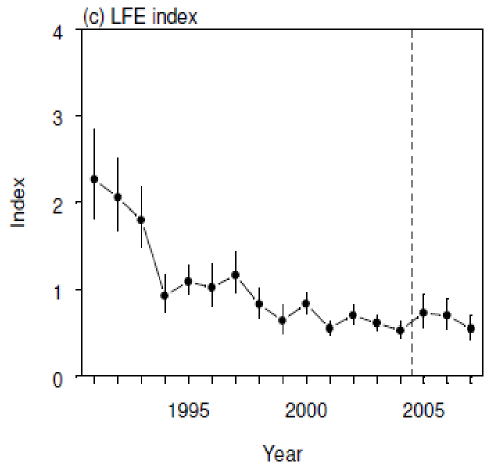


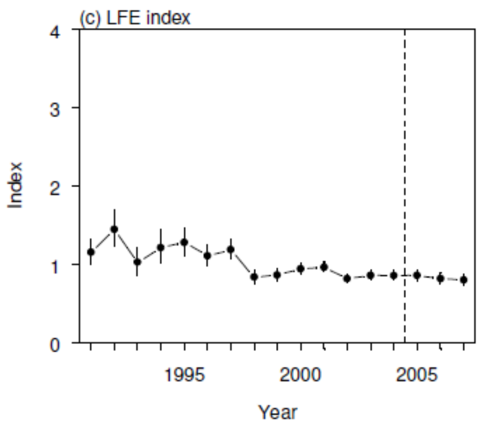
Figure 6-7: Total estimated catch of shortfin (SFE), longfin (LFE) and unclassified eels (EEU) for Southland (left side) and Otago (right side).



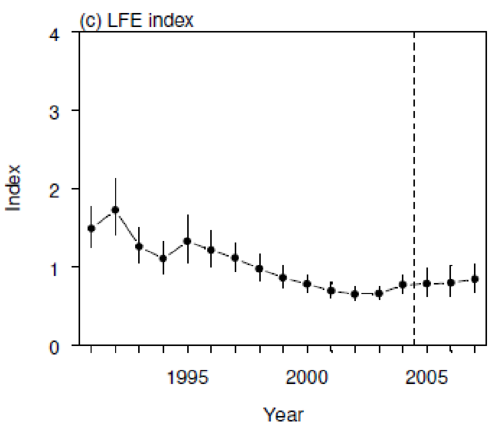
Hawkes Bay



Hauraki



Waikato



Taranaki

Figure 6-8: Standardised CPUE for longfins from a selection of North Island ESAs.

South Island: ignoring the Te Waihora/Lake Ellesmere data, there were indications of slight increases in CPUE over recent years for the 3 sites for which there were sufficient data (collectively, these sites contribute 63% of all longfins caught in the South Island between 1991 and 2006). Certainly it is encouraging to see that the South Island longfin stocks do not show the same marked decline as North Island longfins. However, South Island longfin CPUE was maintained against a backdrop of declining catch. Assigning reasons for such declines are difficult, as they can include market requirements, changes in the demography of fishers, changes to the management of the fishery (like the change from 150 to 220 g minimum size in 1992, and entry into the QMS), and changes in climate and flow.

6.4 Size grades

The CELR system does not include information on size of fish landed. In an effort to obtain information on eel sizes, Jellyman (1993) included results from a questionnaire sent to eel processors in 1979, and again in 1991; the results (Table 6-6) indicated an obvious decline in sizes (although the data were not available by species).

Table 6-6: Percentage of eels (both species combined) of different sizes processed by a South Island eel processor, between 1975-1979 and 1984-1990. (Note: sizes have been converted from imperial measurements.

Size category (kg)	1975-1979	1984-1990
0.2 -0.5	14.4	41.9
0.5- 0.9	27.2	23.4
0.9 – 1.4	21.4	12.0
1.4 – 1.8	15.9	8.0
1.8 – 2.3	10.3	5.3
> 2.3	10.8	9.6

A more comprehensive programme to monitor sizes of eels in the commercial fishery (1995/96 - 1998-99) involved monitoring of fishers landings into processing factories. Eels were identified to species, measured and weighed, and some were sexed and aged. Initially a size–stratified sample of eels was chosen for ageing (i.e. representative of the complete length distribution), but subsequently the ageing was confined to eels about the commercial threshold of 220 g, or considerably in excess of this. The results from all this shed monitoring are contained in a series of reports that form an important baseline data set (Beentjes and Chisnall 1997, 1998; Beentjes 1999; Chisnall and Kemp 2000; Speed et al. 2000). The monitoring then lapsed for a number of years, before it recommenced in 2003/04 as a 'desk-top" system that collated data supplied by processors on the species and size grades of eels they processed. This has proven to be a cost-efficient means of maintaining and understanding of the trends in sizes of eels and where they are landed in the North Island, although it does not provide information on individual eels – hence there are no further length-frequency distributions or information on age and growth. For the South Island, the programme to date has only been able to be applied to ANG 15 i.e. Southland and Otago.

North Island. The programme requires the cooperation of the eel processors (2 main processors), as they supply monthly returns of the quantity of each species, sorted by weight grades, and allocated to a catchment (or part of a catchment). For the latter, reporting is according to a series of maps that divide the North Island into a series of 65 sub-areas i.e. areas within the existing 12 ESA's, and 4 QMA's. There are small differences between processors for the size grades used, as these are usually determined by market requirements; also individual processors often have different size grades for both species. Most processors have gone to a voluntary minimum weight of 300 g.

Overall, three size grades are usually used

Shortfins: 200(300) – 500 g, 500 – 1000 g, > 1000 g

Longfins: 200 (300) – 500 g, 500 – 1000 g (or 1200 g), > 1000 g (or > 1200 g).

The value of these data is that it enables the harvest of both species of eels to be monitored at reasonably small spatial scales (by three reasonably coarse size grades). However, provided these grades are kept consistent over time, these will provide a very useful index of changes in grades over time. With some assumptions, it is possible to convert total weight of eels into total numbers, an even more useful statistic for evaluating harvest levels. Of course, the value of the data is proportional to the length of years of recording, as this enables longterm trends in size and species composition to be evaluated. Again, like CPUE analysis, trends will not only reflect species availability (and hence relative abundance), but market demands, and climatic changes.

There are many ways in which the catch data can be expressed. Figures 6-9 and 6-10 show the total catch of both species (as tonnes, and as % species composition) by ESA, for two consecutive periods (2003/04 – 2006/07, and 2008/09). The main ESA's are consistent between these two periods (ESA 4 = AD, Waikato; ESA 1 = AA, Northland; ESA 7 = AF, Hawks Bay, ESA 3 = AC, Hauraki). Likewise the catch in both periods is dominated by shortfins in all ESA's with the exception of ESA 9 (Taranaki) in 2003/04 – 2006/07.

To see whether the species composition and overall contributions from the various ERA's have changed much over time, data from Jellyman (1993) were used – for these, the unidentified catch was allocated on a pro-rata basis within each ESA. Results (Figure 6-11) are rather similar to Figures 6-9 and 6-10 for the relative importance of the ERA's, with the order for the first three areas again being Waikato, Northland, and Hawke's Bay. However, the species composition shows marked changes – for the earlier period (1983/84 – 1990/91), longfins exceeded shortfin in four ESA's compared with one in the later two periods (2003/04 to 2006/07, and 2008/09; Figures 6-9 and 6-10). More significantly, the overall composition for the earlier period was 59% shortfin and 41% longfin, compared with 77 % shortfin and 23 % longfin for 2003/04 – 2008/09 (data from Beentjes 2011).

Unfortunately, there is a lack of historic data from most North Island processors to observe any trends in the relative proportions of the different size classes. Jellyman (1993) gave data for the proportions of eels of both species < 500 g processed by a major North Island processor (New Zealand Eel). Data in this table (1970 – 1990) can be updated using data from Beentjes (2011) for the same processor, and using eels taken from the same general area QMA 21 (Waikato). The resulting table (Table 6-7) shows the rapid increase in the proportion of eels < 500 g that were processed over the first 30 years, and a reasonably constant proportion over the past two decades. As the original data were not separated by species it is not possible to differentiate this trend by shortfin and longfin. However, the data do indicate a marked increase in the proportion that the smallest size group contributes to factory production over time.

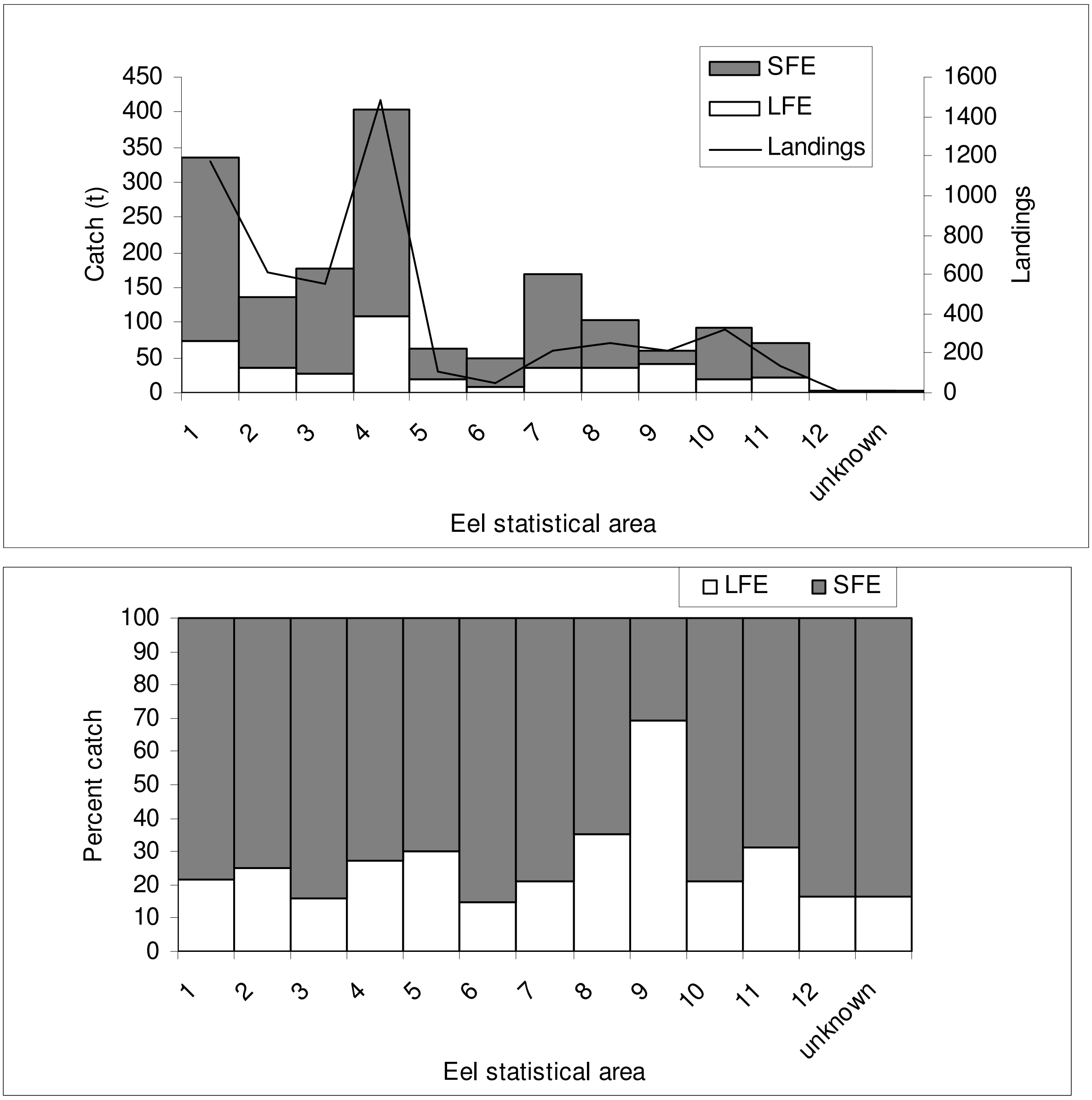


Figure 6-9: Catch of North Island shortfin (SFE) and longfin (LFE) eels and landings from 2003/04 to 2006/07 by ESA. The top graph (a) shows the species actual tonnages, and the bottom graph (b) shows catches expressed as species composition (%).

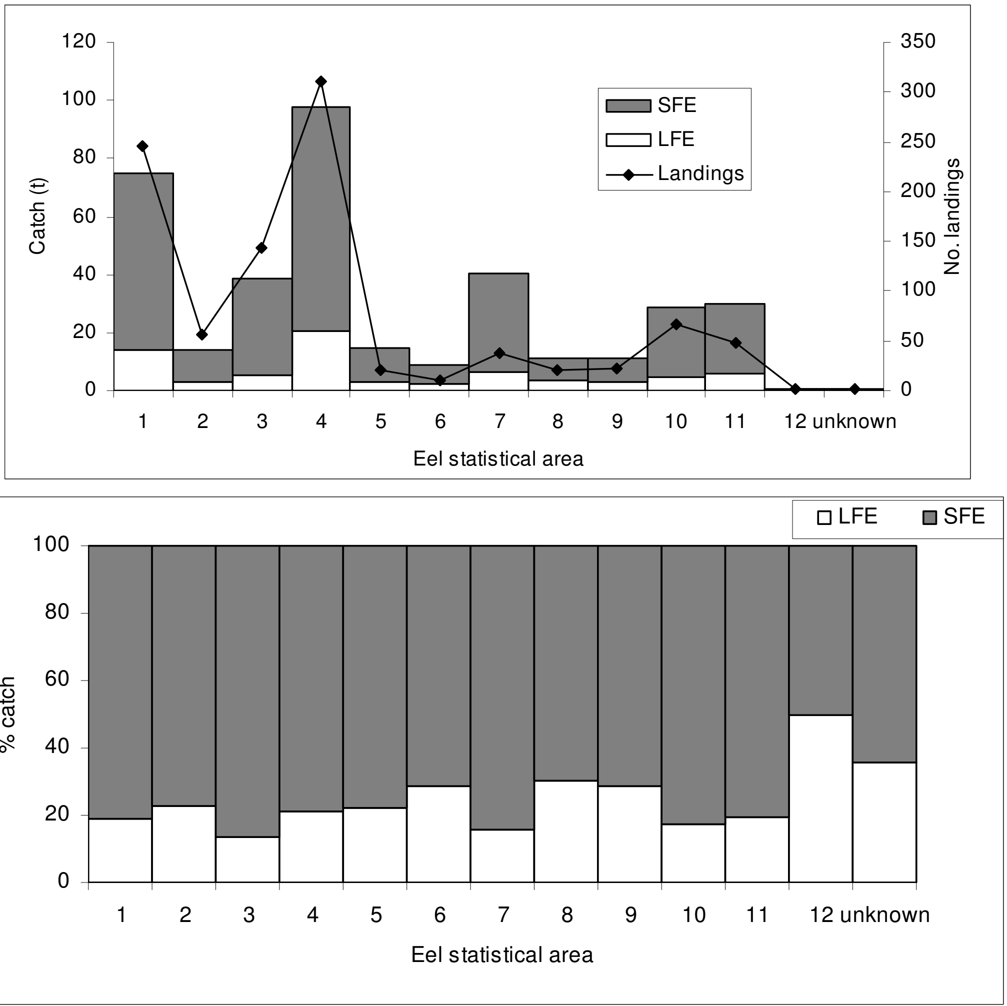


Figure 6-10 Catch of North Island shortfin (SFE) and longfin (LFE) eels and landings in 2008/09 by ESA. The top graph (a) shows the species actual tonnages, and the bottom graph (b) shows catches expressed as species composition (%)

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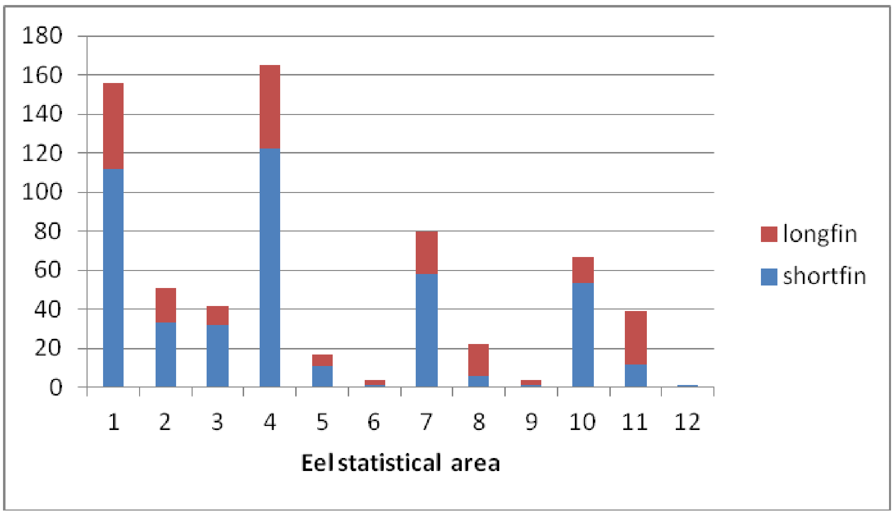

Figure 6-11: Mean catch by species by North Island (ESAs, 1983/84 - 1990/91. (Data from Jellyman 1991).

Table 6-7: The percentage of eels <500 g processed by New Zealand Eel, 1970-2007/08.

Years	% eels
1970	3.1
1971	5.1
1972	16.1
1978	25.2
1982-84	30.3
1985 – 87	35.0
1988 – 90	61.3
2007 - 08	57.4

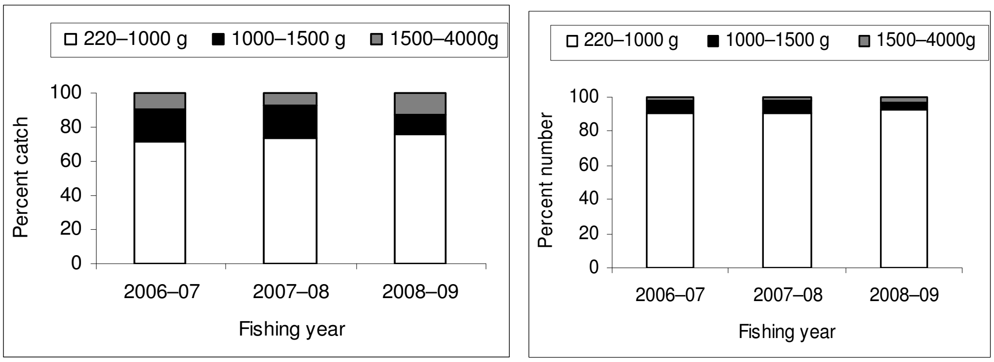

Figure 6-12:The proportion of various sizes and numbers of longfins from QMA ANG 15, processed by Mossburn Enterprises, 2006/07 - 2008/09.

South Island. At present, the South Island data are not available by subarea except for QMA ANG 15 (Otago-Southland). Excluding Te Waihora/Lake Ellesmere, then ANG 15 contributes 53.4 % of the total South Island catch (or 29.1% if Te Waihora/Lake Ellesmere is included).

Size grades differ from those generally used in the North Island and are:

Shortfin 220 – 800 g, > 800 g; longfins 220 – 1000g, 1000 – 1500 g; > 1500 g. The data available for the years 2006/07 – 2008/09 for longfins (Figure 6-12) show no discernible trends, not unexpected from such a short-term dataset.

Historical data from previous questionnaires can be used to compare recent and historic size grades for specific processors. Fortunately, there are data available for Mossburn Enterprises, Invercargill, who have been the major processor in the South Island, probably since the inception of the commercial eel fisheries in the 1970's. The distribution of size grades of each species over the past four decades (Figure 6-13) show marked changes in the size distributions of processed eels. When interpreting these graphs, it should be noted that a 4 kg maximum size limit was imposed for longfins in the South Island in 1995, and there have been changing market requirements for differing sized eels over time. Despite these caveats, it is apparent that the average size of eels processed has declined substantially over time – for longfins, eels < 450 g comprised 14% of the total quantity in the

1970's, but this has steadily increased to > 50% since then. Shortfins show a similar shift towards smaller size classes over time.

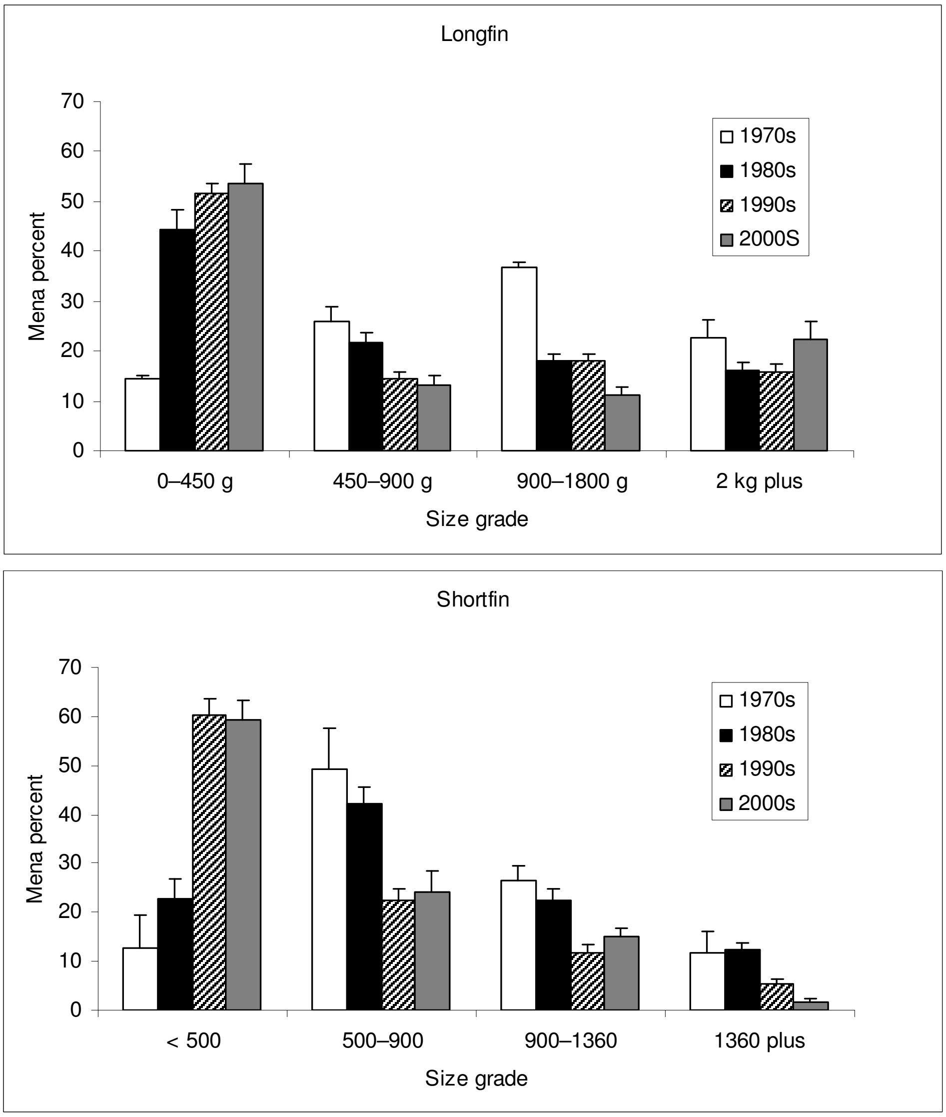

Figure 6-13:Size grades of longfin and shortfin eels processed at Mossburn Enterprises Ltd (Invercargill) in the 1970s, 1980s, 1990s, and 2000s. 1970s years: 1974-75, 1977-78 and 1978-79; 1980s years: 1983-84 to 1988-89; 1990s years: 1989-90 to 1998-99; 2000s years: 1999-2000 to 2006-07. Error bars represent standard errors.

Data collected over the past decade to monitor sizes of processed eels show some changes in the relative proportions of the various size grades (Figure 6-14), but trends differ between processing companies. For New Zealand Eel, the overall trend has been for a reduction in the proportion of the smallest size grade, whereas for AFL the trend in both weight and numbers of eels has been relatively stable. For both processors, the proportion of the smallest size grade (< 500 g) is approximately 40-50%, which is considerably less than the > 50% for South Island longfins (Figure 6-13).

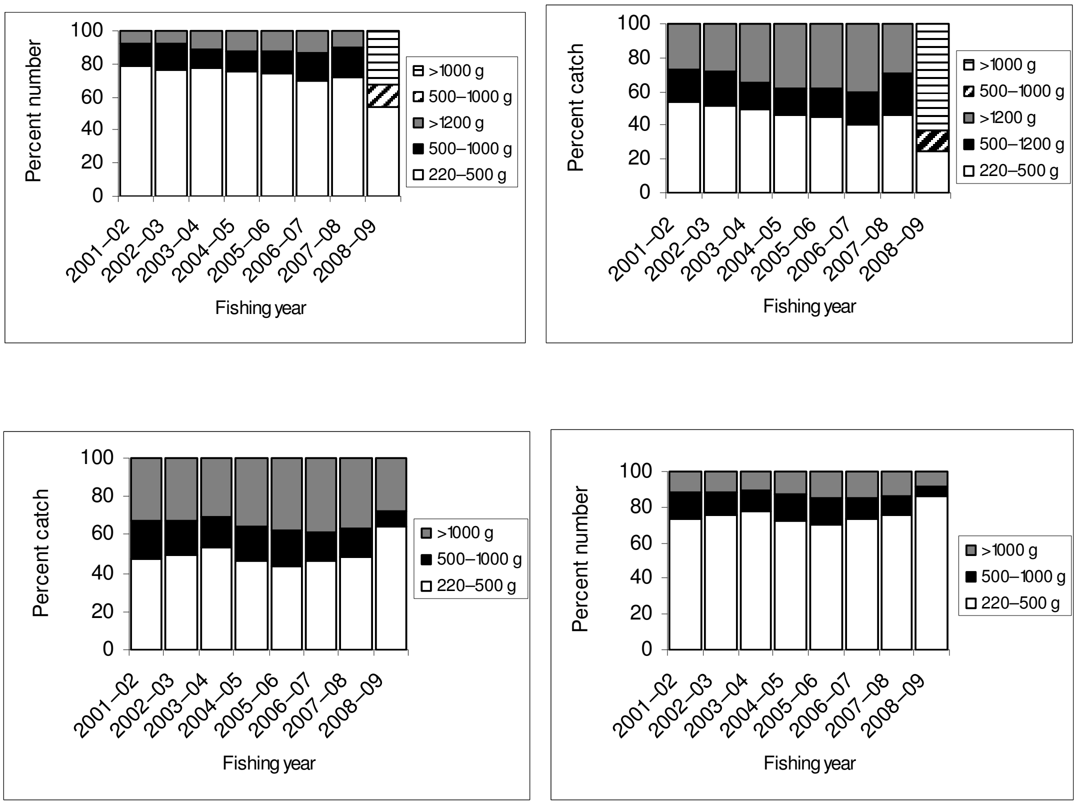

Figure 6-14: Proportion of longfin eel catch and eel numbers in various size grades processed by New Zealand Eel (top) and AFL-Levin (bottom) from 2001-02 to 2008-09.

Conclusions

Monitoring of size grades of eels is a surrogate for more intensive catch-sampling programmes. While it is cheaper and more expedient, it has a number of drawbacks that make interpretation difficult. The main issues are:

- Historic changes from imperial to metric weights
- Lack of information about individual eels (hence no length frequencies, age and sex trends)
- Differing weight categories between processors
- Changes in weight categories used by individual processors over time
- The relative values of different weight classes can reflect market demands
- Shortness of the present time series i.e. 2001/02 to present
- Lack of ESA's available for South Island eels (only ESA's AV and AW at present)
- Changes in the fisheries regulations (e.g. implementation of minimum size of 4 kg for longfins in 1995 for the South island, and 2007 for the North Island)

Over the four decades that eels have been commercially harvested, there is evidence of overall reductions in size of eels processed – for the North Island, this cannot be separated by species, although it is highly likely that similar trends occur for both species. For the South Island, there is strong evidence of a decline in size of both species over time. While some of these changes may be attributable to market demands, changes in fishing regulations etc, there is little doubt that a large proportion of this change will be due to reduced abundance of larger eels.

For example, although longfins grow to a larger size than do shortfins (e.g. >15 kg versus 3 kg), the average size of longfins in commercial catches is almost always less than the average size of shortfins (e.g., Beentjes and Chisnall 1997, 1998; Beentjes 1999), (Figure 6-15), indicating that fishing pressure has not affected shortfin populations to the same extent as longfin populations (Beentjes 1999). Further evidence of the impact of commercial harvest can be seen when comparing the size distributions of eels from seldom fished areas of the same river with sizes from frequently fished reaches (Figure 6-15). Thus in the latter waters, (site 1 in Figure 6-15), the length-frequency distributions of longfins are typically strongly unimodal slightly above the minimum commercial size with relatively few large eels, whereas catches of shortfins are more evenly spread over a wider size range. In contrast, length-frequency distributions of longfins from less accessible areas (site 2, Figure 6-15) have a much higher proportion of large females. Broad et al. (2002) noted a similar trend in sizes of longfin eels from contrasting reaches of the Taieri River, where sizes in less accessible areas exceeded those from accessible and regularly fished areas.

Fyke net fishing is an extremely efficient means of catching eels, especially longfins. In a trial to study this efficiency, Jellyman and Graynoth (2005) determined that baited fyke nets fished for a single night caught between 55 and 89% (average of 74%) of the estimated longfin eel population in the Aparima River, Southland. Similar fishing in a small stream was less efficient, with baited nets catching 42% of the estimated catchable longfin eels present on the first night, and 82% if fishing continued for four nights; baited nets were much less effective for shortfins, catching only 29% of all eels present over four nights fishing (Jellyman and Graynoth (2005).

In a survey of unfished population of longfin eels on the West Coast of the South Island, Jellyman (unpubl. data) simulated the effect of a single night's fishing with baited fyke nets. Depending on the number of recruits that entered the catchment and grew to the same biomass as the captured fish, the most optimistic simulation was that it would take 5 years to achieve the original biomass, although a more realistic scenario was ~ 10 years.

Thus, fyke netting can remove a high proportion of commercial–sized eels, and replacement can take many years (assuming there is adequate recruitment). It is for such reasons that commercial fishers rotationally fish areas, and many fishers, especially in the North Island, enter into agreements with landowners who will effectively give them exclusive fishing rights to an area by refusing access to other fishers.

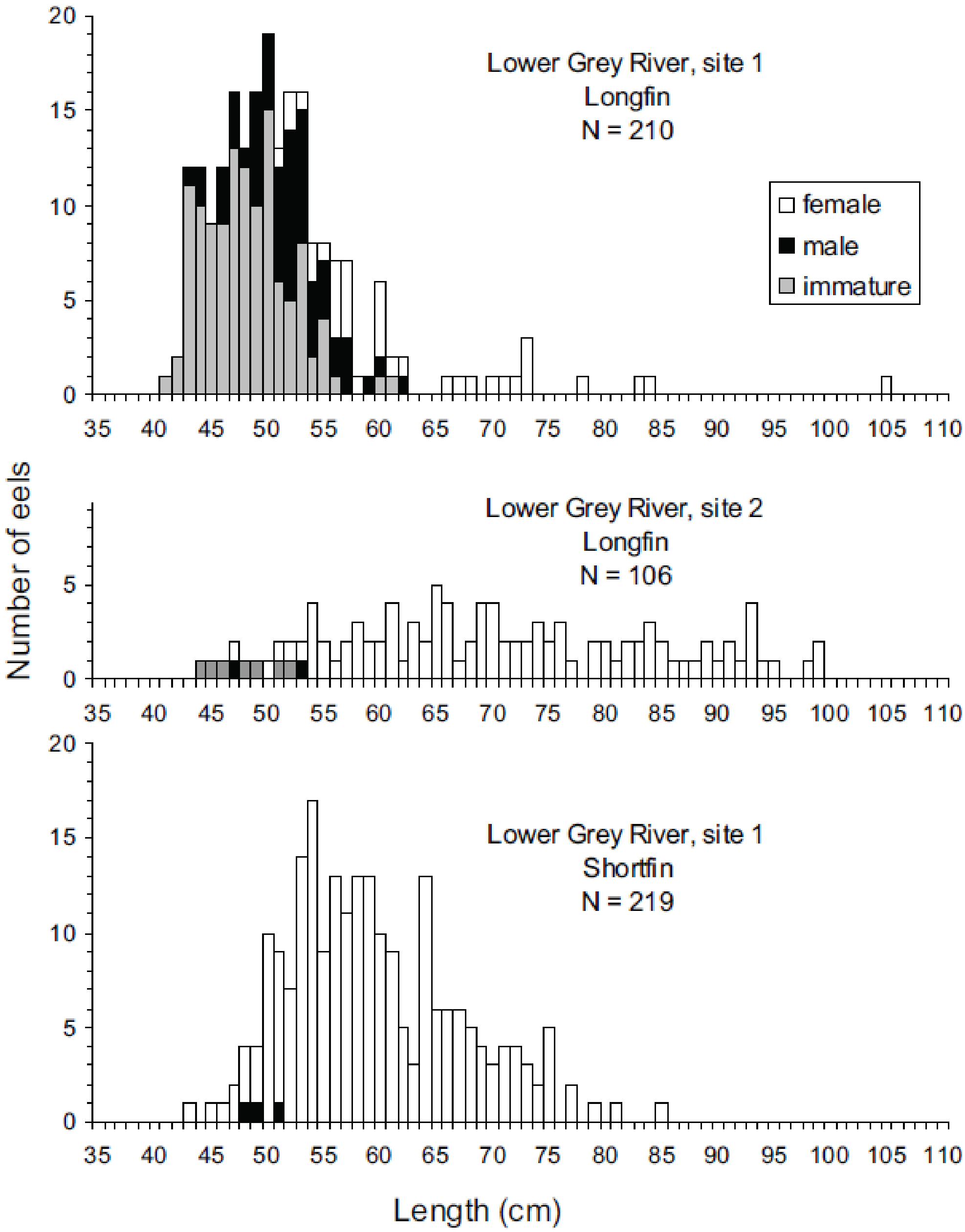

Figure 6-15:Length frequency of longfin and shortfin eels from the lower Grey River, New Zealand/. Site 2 is upstream of Site 1 and less accessible (data reproduced from Beentjes 1999).

6.5 Trends in sex ratios

The national minimum legal size of 220 g corresponds to lengths of 48 and 45 cm for shortfins and longfins, respectively. Given that the mean length of shortfin male silver eels is about 43 cm, then the shortfin fishery is based almost completely on immature females. In contrast, silver male longfins range from 48 to 74 cm (Table 3-1), meaning that both immature males and females are potentially available to the fishery. Sizes at sexual differentiation (review by Davey and Jellyman 2005) are 27–48 cm and 32–49 cm for shortfin males and females, respectively, and 33–65 and 42–64 cm for longfin males and females. Eels are unusual in that sex is not determined genetically, but by environmental factors

(Davey and Jellyman 2005). Thus eels living in high density have a strong likelihood of becoming males, while those in lower density (usually inland) are more likely to become females.

The predominance of female shortfins in commercial catches is apparent from catch sampling programmes; for example, Beentjes (1999) recorded a sex composition of 78% females and 22% males (*n* = 3,050) from South Island catchments. The sex ratios of longfins (Table 6-8) show a slight predominance of females in the North Island and upper South Island regions, but there is a tendency for reduced proportions of females in the lower half of the South Island. In a more detailed study of sex composition in a Southland river, McCleave and Jellyman (2004) recorded only five female longfins from a sample of 471 eels whose sex could be determined. Historically, such areas were dominated by females (Cairns 1942; Burnet 1952). McCleave and Jellyman (2004) suggested that changes in sex ratios could be partly attributed to selective harvest of females but also to changes in the structure of the population resulting from commercial fishing that favoured differentiation of males. Given that the Southland region supports the largest longfin eel fishery in the country, the lack of females in this region was of particular concern.

Table 6-8: The proportions of immature male and female longfin eels recorded from fishery dependant surveys. Regions are arranged by increasing latitude. Data from Beentjes and Chisnall 1998, Beentjes 1999, Chisnall and Kemp 2000, Speed et al. 2000. N = sample number.

Region	Male (%)	Female (%)	N
North Island			
Waikato	33	67	67
Wellington	48	52	150
South Island			
Nelson	56	44	153
Marlborough	49	51	115
West Coast	48	52	412
North Canterbury	37	63	257
South Canterbury	53	47	158
Waitaki	52	48	619
Otago	65	35	1833
Southland	83	17	4368

However, a more recent review (Beentjes 2005) recorded the sex of 2947 longfins from Southland; of the 50.6% that could be sexed (the remainder being “immature”), 58% were males and 42% females, percentages that were very similar to those in Table 6-8 for other parts of New Zealand. Thus, the issue of sex bias in favour of males seems to not be an ongoing issue for Southland eels, although why this change in sex proportions should now be apparent in a long-lived species where sex is primarily determined by environmental factors (Davey and Jellyman 2005) is something of a mystery.

7 Products and markets

7.1 Historical

Historically, most eels were sold as whole frozen eels, sometimes gutted but mostly not (Table 7-1). New Zealand was regarded as a supplier of bulk, relatively low grade and cheap eels. The live trade was commencing, mainly to Billingsgate in London, but also to the Netherlands - virtually all live eels were migrating shortfin male eels from Te Waihora/Lake Ellesmere. Exports to these counties accounted for half of all eels (Table 7-2). In the 1990s there were 23 processing factories operating (Jellyman, 1993), and product standards were variable. Unfortunately export statistics are not separated by species, so it is not possible to determine the proportions of each species per product type or by market place.

Table 7-1: Percentage of eel products exported, 1987-1992 (from Jellyman 1993). Data are by weight of product.

Product	%
Live	16.2
whole frozen	59.8
frozen headed and gutted	5.4
frozen fillets	12.5
frozen other chilled headed and gutted	0.2
Chilled	0.8
chilled headed and gutted	0.1
chilled other	0.3
Smoked	0.9
smoked whole	2.3
smoked fillets	1.4

Table 7-2: Principal countries importing New Zealand eels, 1987-1992 (from Jellyman 1993). Data are by weight of product.

Country	%
Netherlands	34.3
Germany	18.3
UK	21.0
Belgium	13.6
Italy	5.0
France	6.4
Australia	2.8

7.2 Present day

Products and markets have changed substantially over time. Today, the Netherlands constitutes < 1% of the export market (by both quantity and value, Table 7-3), while the United Kingdom has declined to 9% by weight. Germany and Belgium remain important markets at 5.6% and 19.6% (by weight) respectively. The most significant marketing change over recent years has been the substantial increase in the Korean market; over the 6 years from 2005 to 2010, this market has risen from 6.5 % to 75.2 % (Appendix Table 3) – at the same time the Belgium market, the second largest, has fallen from 40.1% to 6.1%. The product sold to Korea is relatively low value, averaging $2.8k/tonne, compared with $12.3k/tonne for Belgium.

Table 7-3: Quantity and value ($NZ1000) of eel exports by country, 2005-2010.

	Quantity		Value	
	tonnes	%	x $NZ1000	%
Australia	25.2	0.6	339.1	1.16
Belgium	868.3	19.6	10659.8	36.51
Brunei	0.1	0.0	2.4	0.01
Bulgaria	7.9	0.2	29.9	0.10
Canada	49.2	1.1	580.4	1.99
China	0.6	0.0	3.7	0.01
Cook Islands	0.0	0.0	0.1	0.00
France	88.5	2.0	1233.6	4.23
French Polynesia	0.3	0.0	7.3	0.03
Germany	249.2	5.6	1775.3	6.08
Hong Kong	157.6	3.6	1750.4	6.00
Israel	1.2	0.0	14.9	0.05
Italy	56.7	1.3	432.4	1.48
Japan	0.2	0.0	5.6	0.02
Korea	2099.5	47.5	5904.4	20.23
Lithuania	4.0	0.1	9.3	0.03
Malaysia	0.0	0.0	0.2	0.00
Mariana Islands	0.0	0.0	0.7	0.00
Netherlands	26.7	0.6	285.7	0.98
New Caledonia	0.0	0.0	0.1	0.00
Portugal	23.4	0.5	62.3	0.21
Russia	105.4	2.4	1027.7	3.52
Singapore	0.3	0.0	7.1	0.02
Switzerland	0.0	0.0	0.1	0.00
Taiwan	143.1	3.2	1057.6	3.62
UAE	3.4	0.1	52.7	0.18
UK	393.6	8.9	2767.9	9.48
Ukraine	14.9	0.3	111.9	0.38
USA	100.1	2.3	1069.4	3.66
Vanuatu	0.0	0.0	1.1	0.00
Grand Total	4419.4	100.0	29193.0	100.00

Historically there were many factories that processed eel, usually as one of a number of marine species they handled. For instance, in the early 1990's there were 23 licenced factories (Jellyman 1993). However, there have always been dedicated eel processing factories, like NZ Eel at Te Kauwhata, and Thomas Richard Ltd (now owned by AFL) at Whenuapai. With the consolidation that has accompanied significant developments in the eel industry over the last decade (including entry in to the QMS), the number of factories has reduced to 4 or 5 (depending whether one is operating as a receiving facility only). With restrictions imposed on inter-island transfers of water associated with controlling the spread of the invasive diatom *Didymosphenia,* there are no longer inter-island transfers of eels. Typically, eel fishers accumulate catches at bankside or in holding tanks, and then deliver them to the factory, or the factories collect the eels in special tankers (one of which had a sign "Eels on Wheels"). These tankers are able to transport eels the length of each island – thus eels caught in Nelson/Marlborough are processed in Invercargill.

Table 7-4: Variation in annual weight (top) and value (bottom) of exported eel products, by overall %.

Quantity								
Product	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Grand mean**	**$/kg**
chilled	0.5	0.0			0.0	0.4	0.2	
chilled other	0.0	0.0	0.1	0.4	0.2	0.0	0.1	
chilled whole	0.4	0.0	0.0	0.1	0.2	0.0	0.1	
frozen headed and gutted	5.3	26.0	9.8	6.4	3.8	1.3	6.5	
frozen other	30.7	21.9	17.8	22.3	25.5	9.2	17.7	
frozen whole	21.2	22.1	47.8	28.2	13.7	63.8	41.9	
Live	41.1	29.6	24.2	42.1	55.8	25.0	33.0	
Smoked	0.7	0.1	0.3	0.5	0.8	0.3	0.4	
Whole	0.1	0.2	0.0	0.0	0.0	0.0	0.0	
Grand Total	100	100	100	100	100	100	100	
Value								
chilled	0.3	0.0			0.1	1.2	0.3	35.11
chilled other	0.0	0.0	0.2	0.6	0.4	0.0	0.2	12.33
chilled whole	0.6	0.0	0.0	0.1	0.3	0.0	0.1	9.49
frozen headed and gutted	3.6	24.1	12.0	6.0	4.1	1.3	7.9	8.80
frozen other	35.8	28.5	35.8	40.9	38.9	26.3	34.4	12.39
frozen whole	17.5	19.1	22.7	16.2	10.6	25.6	19.1	9.62
live	41.1	27.9	28.7	35.4	44.2	44.6	37.1	9.43
smoked	1.0	0.2	0.5	0.8	1.4	1.1	0.9	22.73
whole	0.1	0.2	0.0	0.0	0.0	0.0	0.0	5.97
Grand Total	100	100	100	100	100	100	100	11.81

Similar to the situation 20 years ago (Table 7-2), whole frozen eel is still the dominant export category (Table 7-2), followed by live eels. Smoked eel brings the highest unit price (Table 7-4 - ignoring the undefined "chilled" category), but remains a very small proportion of overall product. While there has always been interest in maximising the value of the product to New Zealand, the demand has usually been for relatively unprocessed eels that may be further processed (e.g. jellied, smoked) in the importing country.

Using the value data from Table 7-3, the approximate total annual value for the eel fishery over the six years was $NZ4.86m. Because of the lack of information by species, these product and export data shed little light on the status of longfin, but do serve to indicate there has been little change in the type of product exported over time, but significant changes in recent years with importing countries.

Virtually all commercially caught eels are exported; there is a small market within New Zealand for particular ethnic groups who have a history of eating eels (Māori, western Europe, Pacific), and also a market for smoked eels to the delicatessen and restaurant trade. Comments received from one processor indicated that recently, the overseas smoked eel market has been poor, so most eels have been sent live to Asia and also Asian communities in US and Canada. Further, the Belgian market for eel pieces has been a very important one for New Zealand. Traditionally, this market prefers wild eels to cultured eels from Asia, as the latter have a higher oil content but are softer and tend to fall apart during processing, whereas wild eels are firmer. However, when the market for farmed eels (~ 150 g) into Japan (kabayaki = a traditional grilled eel dish) is poor or saturated, Chinese eel farmers on-grow their eels to a larger size and sell into Europe. This practice can destabilise the European market, although there has been some resistance to buying Chinese eels due to an over-dependence upon antibiotics.

The same processor commented that up to one kg, shortfins are easier to market than longfins. Larger than one kg, both species are equally marketable, especially the market for larger longfins in Taiwan. Shortfins are not very good for smoking until about 1 kg whereas longfin are suitable for smoking from 300 grams upwards. At the time of writing, there has been a substantial increase in the price that New Zealand eels are fetching on overseas markets, although details are scarce.

8 Management of eels

Most fisheries in New Zealand are managed under the Quota Management System (QMS) which involves:

- Establishing Total Allowable Catches (TAC).
- Establishing Total Allowable Commercial Catches (TACC).
- Allowances of recreational, customary, and other sources of fishing-related mortality.
- Regulations and other management controls (including Fishery Plans).

Setting the TAC is usually done under Section 13 (s 13) of the Fisheries Act 1996 whereby the TAC is set at a level that can maintain the Maximum Sustainable Yield (MSY) i.e. the maximum yield that can be taken from a stock without impairing its renewability through growth and reproduction. In cases where there are insufficient data to calculate MSY (often referred to as B_{MSY} meaning the average stock biomass), or if the stock is part of an international agreement (like southern bluefin tuna), or the stock is managed on a rotational or enhanced basis, the TAC can be set under section 14 (s 14) of the Act. This section provides more flexibility and can include such measures as area closures.

South Island eels are managed under s 13, which should involve estimation of a B_{MSY} and periodic review of this figure. Perhaps in recognition of the difficulty of achieving this, North Island eels, introduced into the QMS four years after South Island eels, are managed under s 14 of the Act. Therefore, in the absence of the need for a MSY, North Island eels can be managed on the basis of observed trends in such indicators as total catches and catch-per-unit-effort. Hence the 2011 Eel Working party plenary report stated "Each species of eel comprises a single stock, and these can be more appropriately managed using an alternative to the maximum sustainable yield (MSY) approach, which is available under s. 14 of the Fisheries Act 1996. To that event, standardised catch- per -unit -effort analyses have been conducted for the commercial shortfin and longfin eel fisheries from 1990/91 to 2006/07 for all North Island Eel Statistical Areas (ESAs) and to 2005/06 and for all South Island ESAs". While South Island eels should theoretically be managed by adjusting the TAC to achieve the MSY, the Working Party has adopted the more pragmatic approach of considering South Island eels in a similar manner to North Island eels meaning that trend indicators are used to assess the well-being of the eel stocks.

The current management process for eel fisheries involves an annual meeting of the Eel Working Group, a mix of fishery managers (Ministry of Fisheries), iwi (variously representing customary and commercial interests), commercial (fishers, processors, Seafood Industry Council), the Department of Conservation, and research providers. This group discusses research priorities, reviews research outcomes, and also reviews the annual report on eels from the fisheries assessment plenary (written by Ministry of Fisheries staff). Because of the widespread nature of the eel fishery, separate North and South Island meetings are usually held. The consultation process specifically requires that Māori will be given the opportunity to comment on the customary use and management of the stocks; likewise, before changing a TAC, a number of factors must be considered including any regional policy statement, regional plan, or proposed regional plan under the Resource Management Act 1991; any effects of fishing on the stock and the aquatic environment; the natural variability of the stock; any conservation services and any relevant Fisheries Plan.

When North Island eels entered the QMS at the start of the 2004-05 fishing year, the initial TACC's for most areas were set at less than the average annual commercial catch made between 1990/91 and 2001/02. This was in accord with the Minister of Fisheries intention to improve stock structure (size composition) and abundance of eels over a 10 year period (Allen 2010). After a review of these catch limits was undertaken for the start if the 2007/08 fishing year, the TAC and TACC for both shortfin and longfin in the North Island were further reduced; these reductions were not uniform across all QMA's – thus reductions in North Island QMA's for shortfin ranged from 13 – 42% with an average of 25.7 % across all areas; reductions in longfin were much greater, ranging from 49 – 78%, with an average of 57.7%. This is the most recent reduction in TACC for all eel stocks.

The Eel Working Group has expressed concern about the status of longfin eels for several years. For example, in a summary statement of the assessments of sustainability for the 2007 – 08 fishing year, the working group said:

> "Estimates of current and reference biomass are not available. The working group recognises that there are no stock assessments, or reliable data or time series on which to base specific recommendations on catch levels. Given the biology of eels, there is a high risk that the current exploitation levels for longfin eels in particular, coupled with past and present anthropogenic impacts, are not sustainable. Based on available information, the Working Group does not consider that the same risk applies to shortfin eels, although caution is required given the nature of eel biology and exploitation before spawning escapement.
>
> The Working Group considers that more specific management action is required to improve the spawner escapement of longfin eels. It is not possible to recommend specific reduction in TACs but measures are required to improve the spawner escapement of longfin eels to improve recruitment. Measures could include reductions in catch levels, changes to size limits, and area closures".

In response to such (and prior) concerns, three areas were closed to commercial fishing in 2005 i.e. the Mohaka and Motu Rivers, and much of the Whanganui River. In October 2007, there were significant reductions in North Island longfin quota (as indicated above), and the introduction of a 4 kg upper size limit for North Island and Chatham Island eels (to be consistent with South Island regulations).

The 2010 Plenary report of the Eel Working party reiterated many of the concerns raised previously.

> "A consequence of the entry of commercial eel fisheries into the QMS has been the loss of a considerable number of experienced commercial fishers, who have opted to sell their ITQs. For instance, there were 70–80 commercial eel fishers in the South Island prior to QMS introduction, but now there are only about 20. There has also been an overall reduction in commercial fishing activity, as security of quota holdings has meant that

> commercial fishers can fish more conservatively, often on a rotational basis if access agreements can be made with landowners.
>
> Because of a lack of stakeholder involvement in the management of key fisheries, current Government management initiatives are in the development of Fishery Plans, whereby collaborative plans for particular species, stocks and areas can be drawn up cooperatively by fishery managers and industry stakeholder groups. Whether freshwater eels will constitute a single national plan, or a series of regional plans, is uncertain at this stage".

In addition to Government regulations, the eel industry has imposed some voluntary constraints on commercial fishing. The main ones are:

- No capture of silver (migrating) eels – the exception is in Te Waihora/Lake Ellesmere.
- Increased escapement tubes that effectively increase the minimum size from 220 to 300 g (industry representatives mention that the expected downturn in harvest did not eventuate, partly because this change to larger eels was not adopted by all fishers simultaneously).
- Fishers entering into informal agreements with landowners for exclusive access rights – this enable more conservative and rotational fishing.
- One North Island company have not been fishing their longfin quota in recognition that the longfin stocks are under pressure, while Ngai Tahu have not fished much of their South Island quota as they wish stocks of both species to rebuild.

Recent management initiatives include the publication of a draft Freshwater Fisheries Plan by the Ministry of Fisheries, and a joint initiative by iwi and commercial fishers to develop a National Eel Association. This latter agency is still in a formative state, and will require the support of Māori agencies like Te Ohu Kai Moana, Aotearoa Fisheries Ltd, and the Te Wai Māori Trust; from the commercial side, it would need the endorsement of EECo (Eel Enhancement Company, who represent the North Island commercial eel industry) and it's South Island counterpart, the South Island Eel Industry Association. It is understood that the main purpose of this association would be to provide a joint forum of both customary and commercial users, to make recommendations about management and research, and be environmental advocates.

9 Overview of status of longfin eels (past and present)

Several years ago MFish requested a review of the status of longfin. This review (Jellyman et al. 2000) reviewed available data "to see whether there is evidence of a decline in the recruitment of longfinned eels (*Anguilla dieffenbachii*) in New Zealand waters. Data reviewed were glass eel and elver catches and species proportions, age composition of both juvenile and adult eels, changes in abundance and size distributions of longfins; computer models were then developed to simulate the influence of changes in recruitment on age and size composition of populations".

This review found that:

- The data on glass eels and elver transfers were too few and too variable to provide any clear evidence about trends in longfin recruitment. In the absence of measures of effort, it was not possible to determine whether differences in catches and species proportions reflected changes in absolute abundance.
- From the year class composition of adult eels, there was no evidence of the same strong year classes being present at the various sites (i.e. no evidence that longfin stocks are maintained by intermittent years of strong recruitment).
- The age structure and survival rates of juvenile eels showed strong evidence that glass eel recruitment has declined in two North Island and 3 South Island study streams.
- Population models indicated that recruitment is highly variable both between years and between waters and it was most unlikely that recruitment has declined at a steady rate. The rate of decline averaged about 7% per annum since 1980; on this basis, glass eel runs were estimated to be a quarter of the size of runs prior to commencement of commercial fishing in the early 1970's.
- Low recruitment of longfin glass eels has led to an unbalanced population structure dominated by old eels. Today, commercial fishers generally catch relatively small (<600 mm) longfins, whereas large (>700 mm) females are largely restricted to lightly fished areas.
- There had been a major decline in the size of longfins caught over the past 20 years. Computer models indicated crop rates might be as high as 20% y^{-1} in some waters and show that this level of harvesting will lead to a rapid decline in stocks.
- Models indicated that few females survived to spawn at comparatively low fishing rates of 5–10% per annum and that the upper size limit (4 kg) for female eels was virtually ineffective. In addition to harvest, eel numbers will have been reduced by dams preventing access to many upland waters, migrating females being killed by turbines, and reduction/loss of lowland streams and wetlands through channelisation and drainage.

The net result of these observations on age composition and the implications from population modelling, was that longfins are being overfished and this had significantly affected recruitment. Prediction from the models was that the rate of

> decline in stocks would accelerate in future. This report maintained that these conclusions had important implications for the management and conservation of the longfin stocks. “If the fishery and stock of New Zealand longfins is to be maintained, then further conservation measures need to be considered, such as complete closures of particular rivers or fisheries to maintain the breeding stock. Reduced minimum legal size and catch limits are unlikely to be effective because of the slow growth rate, low mortality rates and great age at maturity of female longfins. Because of the slow growth rates and correspondingly long response time of longfins to reduced recruitment, it is important that additional protective measures be implemented in the immediate future….. on a national basis”.

In a subsequent review, Jellyman (2009) summarised 40 years of the impacts of commercial fishing on eel stocks as follows: “The two main species of freshwater eels in New Zealand, the shortfin *Anguilla australis* and the endemic longfinned eel *A. dieffenbachii*, are extensively commercially exploited and also support important customary fisheries. Since there are no commercial glass eel fisheries in New Zealand, other indices must be used to indicate changes in recruitment over time. While there is some anecdotal evidence of reductions in glass eel recruitment, there is evidence of poorly represented cohorts of longfins within some populations, and modelling of these data indicate a substantial reduction in recruitment over the past two decades. Growth of both species is typically slow at 2–3 cm per year, meaning that both species are susceptible to commercial capture for many years until spawning escapement. Extensive commercial fishing has resulted in more substantial changes in length-frequency distributions of longfins than in shortfins; likewise, regional reductions in catch per unit effort are more significant for longfins. Theoretical models of silver eel escapement indicate that longfin females are especially susceptible to overexploitation. Shortfins would have been more impacted than longfins by loss of wetlands, but the impact of hydro stations on upstream access for juvenile eels and downstream access for silver eels would have been more severe for longfins. Overall, there is no clear evidence that the status of shortfin eel stocks has been seriously compromised by the extensive commercial eel fishery, but there is increasing evidence that longfins are unable to sustain present levels of exploitation”.

Jellyman (2009) included the following summary (Table 9-1) that reviewed data at the time of the original presentation (2003).

With respect to longfins, this paper concluded that “In contrast [to shortfins], longfins are slower-growing, have longer generation times, and have been more affected by reduced upstream access; as well, there is some evidence of reduced recruitment and CPUE. Whereas it might be expected that high fecundity in species like eels confers high resilience to overfishing with a consequent low likelihood of extinction, this is not supported by either fishery theory (Sadovy 2001) or studies (Sadovy and Cheung 2003). When reviewing criteria that describe fish most at risk to overexploitation, Sadovy (2001) noted that such species are usually relatively large, long-lived, and slow-growing, with late sexual maturation and often with a limited geographic range. Longfin eels exhibit all these criteria and, in addition, are semelparous, which accentuates their vulnerability.

The vulnerability of longfins to even relatively light fishing pressure led Hoyle and Jellyman (2002) to recommend conservative management based on the precautionary principle. In response to increasing concern about the status of longfins, a number of recent management initiatives have been designed to provide a greater measure of protection to this species, including catch-and-carry programs to transport juvenile eels above hydro dams, continuing research on silver eel bypass options, reduced quota for North Island longfins, increased reserve areas, and voluntary bans by commercial fishers on catching silver eels. Continuation of monitoring recruitment at index sites is of obvious importance in assessing whether there is evidence of changes in recruitment. Of course, given the long generation time for female eels in New Zealand, the full impact of changes in recruitment may not yet be evident in the wild eel fishery".

Table 9-1: A summary of the indicators of the status of shortfin and longfin eels at 2003. ? = not known; O = OK or no apparent change; x = significant (local) negative change; X = substantial (national) negative change(from Jellyman 2009).

	Shortfin	Longfin
Recruitment issues		
Glass eels	?	?
Juvenile eel age/size abundance	O	X
Cobort analysis	?	X
Fishery impacts		
Sex ratio	O	X
Size changes (commercial fishery)	X	X
CPUE	X	X
Silver eel escapement (modelling)	O	X
Habitat impacts		
Wetland loss	X	O
Access – upstream at hydro stations	X	X
- downstream at hydro stations	x	X

In a review of the spawning escapement of longfin eels from throughout New Zealand, Graynoth et al. (2008), used relationships between biomass of longfins and length of waterways or areas of lakes, to estimate the present total biomass of longfins throughout New Zealand; they also used models to predict virgin biomass (i.e. the biomass prior to the commencement of commercial fishing). Their estimates were that the virgin biomass (24 350 t) was approximately twice present biomass (12 200 t). Of the present biomass, 7% is in waters closed to commercial fishing that provides safe egress for migrating eels; 17% is in waters that are protected in their upper reaches but where migrating eels could theoretically be caught on their downstream migration; a further 25% is in small streams that are rarely fished. Overall then, as migrating eels are not fished for (and are "protected" by voluntary agreements by fishers), approximately 49% of the total tonnage of longfin is either in reserves or in areas that are rarely fished. Assuming the total biomass estimates are reasonable, then current harvest levels of ~ 200 t (the average of the past 6 complete fishing years, 2003/04 – 2008/09) would represent annual harvest rates of about 3.3% in waters open to commercial fishing, and 1.6% over all waters. Compared to many marine fisheries where harvest rates can be 10% or greater, these are modest rates, but seemingly such a long-lived and semelparous species must be harvested conservatively.

In the decade 1990-2000, the annual average harvest of longfin was 542 t, which would equate to a harvest (exploitation) rate of 8.9% of longfins in fishable waters, or 4.4% of longfin in all waters. Simulations of the effect of different levels of harvest on longfins in the Aparima River, Southland, suggested that a harvest rate of 5% would reduce overall biomass of longfin by 25%, while the effect at harvest levels of 10% and 20% would be 38% and 50% respectively (Graynoth et al. 2008). Because fishing practices are selective for larger longfins (i.e. baited fyke nets tend to catch the larger eels within the population first, probably because they are the eels that forage more widely and are attracted to baits, and their presence is inhibitory on smaller eels), then even modest exploitation rates can harvest a disproportionately high proportion of larger (female) longfins. Such simulations start to explain why this species is so vulnerable to harvest, as the spawner success can be expected to be highly dependent upon the number of spawning females, rather than males, and selective removal of females can therefore impact on total egg production.

In view of the present review, a rewrite of Table 9-1 for both species would be as follows: (Table 9-2)

Table 9-2: A summary of the indicators of the status of shortfin and longfin eels; comparison of estimates in 2003 with 2011. ? = not known; O = OK or no apparent change; x = significant (local) negative change; X = substantial (national) negative change. Indicators in italics are new.

	Shortfin		Longfin	
	2003	Present	2003	Present
Recruitment issues				
Glass eels (national)	?	?	?	?
Glass eels (Waikato)		x		X
Juvenile eel age/size distributions	0	0	X	X
Cohort analysis	?	?	X	X
Fishery impacts				
Sex ratio	0	0	x	0
Size changes (commercial fishery)	x	X	X	X
CPUE	x	0	X	x
Silver eel escapement (modelling)	0	0	X	X
Ability to take TACC		0		x
Sampling occurrence				
Electric fishing occurrence		0		X
Habitat impacts				
Wetland loss	X	X	0	0
Access – upstream at hydro stations	X	X	X	X
- downstream at hydro stations	x	x	X	X

There is still uncertainty about glass eel recruitment trends due mainly to the brevity of the data. However, the relative absence of juvenile longfins within many waterways is of considerable concern. Most other factors are not determined to have changed significantly since the 2003 assessment, although there are a few exceptions and two additional factors have been added (ability to take TACC, and electric fishing occurrence). For CPUE, the most recent assessments indicate overall declines in the North Island but slight gains in the South Island. One of the new factors is the records of longfin recorded from the New Zealand Freshwater Fish database where there is strong evidence of decline in the occurrence of longfins. The ability to catch the TACC has been added, although this is not a factor that should be given much weight as part of the reason that longfin catches are below the TACC is because longfin are not being targeted by some fishers (e.g. Te Waihora/Lake Ellesmere) or quota is not being fished. “Improvements” between the 2003 and 2011 assessments for longfin are the previous concerns about lack of females in populations seems to have diminished, and South Island CPUE has stabilised or increased slightly. However, the overall assessment shows that collectively, the status of longfins is more dire than shortfins, and of the two additional factors introduced for the present assessment, the reduced incidence of longfin from electric fishing results has a strong negative influence.

Overall there are strong indications in the review data that longfin eels are being fished at an unsuitable level. In arriving at this conclusion, it is emphasised that it is important to review the data in its totality, rather than on a piecemeal basis as some trends are equivocal. Determining the quantity of eels that should escape for spawning each year is extremely difficult, and is only one part of the biological conundrum that eels present – for instance, the relationship between the biomass of spawners and recruitment of glass eels is uncertain – while it is reasonable to assume that large recruitment in any one year is a result of a large escapement of spawning eels the previous year, this fails to take into account spawning success and the likelihood of variable larval survival in an oceanic world where current patterns and thermal gradients can vary considerably between years.

The most meaningful measure of stock wellbeing is the extent of annual recruitment. For New Zealand eels we lack the extensive databases on Northern Hemisphere countries – ironically, these databases have been based on commercial glass eel fisheries, and will have exacerbated the overfishing problems associated with these stocks. The indicators we do have of glass eel and elver recruitment are “noisy”, but there is a disturbing trend towards the virtual lack of juvenile longfin eels from electric-fished samples of eels, especially in South Island East Coast waters. Similar to recruitment of the European eel, it is likely that those regions furthest from the main area of glass eel arrival will show the most severe symptoms of recruitment reduction or failure. The fact that a major catchment like the Waitaki has recruitment measured in a few thousand eels at Waitaki Dam is alarming – average recruitment of longfins at this site over the past 8 seasons has been 1% of longfin recruitment at Karapiro Dam (on a river of comparable size) i.e. average recruitment (2003/04 – 2010/11); Waitaki Dam = 3280 longfins; Karapiro = 299 875 longfins.

A problem in interpreting commercial fisheries data is the time lag from recruitment until eels enter the fishery. Depending on the size at harvest (legally 220 g, but widespread practice is 300 g), and growth rates, this lag can be from 10-15 years. Thus fishers perceptions that there are sufficient recruits are based on their observation of the abundance of eels immediately below the size limit (small eels retained in fyke nets), which does not reflect recruitment over the past decade or more.

The eel life-history that occurs at sea is beyond our control. The only way in which we can affect this is by enhancing opportunities for production and escape of migratory eels. The ways to do this are via conservative management of rates of exploitation, and setting aside reserve areas. As each eel harvested is one less potential spawner, arguably the latter method of reserve areas is the more effective. This is not to neglect the importance of conservative fishery management, and ultimately there may need to be a decision made about whether the risk of maintaining a modest commercial and customary fishery is warranted given the status of the national longfin stock. In the absence of unequivocal evidence of stock depletion and damage, the fishery managers are understandably reluctant to impose more draconian measures to seriously reduce the longfin eel fishery, such as invoking the Precautionary Principle. While further reductions in longfin quota might be contemplated, or even closure of the commercial longfin fishery (with associated compensation for quota holders), any move to prohibit customary harvest would no doubt be met with spirited opposition.

Despite some uncertainty about some of the fishery trends, there is no doubt that the longfin resource is seriously depleted – whether stocks can cope with the impacts of historic and present levels of exploitation, compounded by issues of reduced access and the annual loss of spawning eels at hydro and pumping stations, is uncertain. Biological extinction seems unlikely for such a widespread and persistent species, partly because as densities reduce, exploitation become less cost-effective; however, this assumes targeted fishing, but a danger with undesignated species quota (as in the South Island) is that longfin can always be landed as a "bycatch", and overfishing is possible. The European and American eels are some of the most widespread freshwater fish and the ecological flexibility of these species means they are able to occupy a very wide range of habitats. Despite these adaptable characteristics, both species are endangered, necessitating radical management options. Although the New Zealand longfin is also a wide ranging and adaptable species, there is little comfort from consideration of its northern hemisphere counterparts that its future is assured.

Longfin eels are intrinsically, ecologically, and economically important. They are habitat and feeding generalists, and probably our most tolerant native species. Despite these adaptable characteristics, they exhibit others that make them vulnerable to over-exploitation

These are:

- A catadromous life history (oceanic spawning at great distance from their freshwater habitat).
- Semelparity – spawn only once at the maximum size for each sex.
- Environmentally determined sex – hence widespread events like climate change could have significant impacts.
- Slow growing.
- Females are older and larger than males (and so vulnerable to capture for much longer).
- Easily caught, especially large females.
- Their habit of extensive upstream migrations in rivers means they are impacted by hydro dams and weirs.
- Upstream colonisation can take many years in large catchments.

Further, commercial fishing has occurred within less than one generation, so the full impact of this may be yet to come. For these reasons, and the evidences in this review of detrimental changes to the abundance of the species, careful consideration should be given to reducing the exploitation of this species, while enhancing passage and habitat opportunities.

9.1 Possible management initiatives

To provide additional protection to longfins, a number of management issues should be considered.

- Establishing some national consensus that the longfin eel stock is showing signs of being over fished, and the rebuilding of stocks will take a coordinated effort by both customary and commercial users. This might require local moratoriums or rahui on selected waters.
- Issuing South Island quota by species (and setting a low quota for longfins)
- Setting aside additional reserve areas (entire catchments)
- Encouraging “put and take” enhanced fisheries in hydro lakes, and offsetting this catch by reduced catch downstream where migratory eel escapement is unobstructed.
- Discourage harvest of any longfin migrating eels (presently a voluntary agreement is in place for commercial fishers, but there is nothing equivalent for customary fishers).
- Require best practice guidelines be in place to facilitate up and downstream passage of migrating eels at all significant hydro dams and flood gates.
- Investigate the extent that lowland pumping stations result in significant mortality of migrating longfin eels.
- Implement more elver transfer recording sites (e.g. reactivate the Roxburgh Dam site).

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Appendix A

Table A-1: Length distributions of samples of electric-fished longfin eels from sites around New Zealand.

	Mataura 2008	Horokiwi 2007	Pigeon bay 2007	Te Maari 2007	Company Creek 2004	S Canterbury 2010	Mokihinui 2009	Motu 2009	Aparima 2002	Kaikoura 2009	1996	Horokiwi Stream 1997	1998	1996	Pigeon Bay Stream 1997	1998
50-99	2	48	15	147	17		3	34	3	6	9	5	19	25	24	18
100-149	30	40	24	135	66	1	112	118	87	15	27	48	23	51	40	51
150-199	29	36	25	126	35	1	52	33	54	12	37	60	33	66	41	76
200-249	20	50	46	96	12	5	37	16	65	10	38	70	31	87	90	89
250-299	24	46	46	45	10	6	25	7	46	18	34	50	49	86	77	94
300-349	20	36	35	26	21	5	16	2	52	27	46	61	37	72	79	58
350-399	24	48	19	19	5	10	17	4	57	13	33	25	38	58	41	46
400-449	24	32	20	17	7	8	17	2	70	10	40	34	34	28	35	24
450-499	17	36	12	10	1	6	21	4	61	10	31	21	28	15	23	20
500-549	13	48	13	6	4	7	3	3	29	6	14	20	16	13	14	8
550-599	12	36	6	2	3	8	4	2	10	2	13	8	12	11	13	5
600-649	4	4	2	2	3	7	1	4	2		1	4		5	4	4
650-699	1	2	5	2	1	4	1	1	3		2	3	1	2	1	3
700-749		4	1	3		9	2	1	2			2	1	1	1	2
750-799		4	1	3	1	5	1	1			1	2	2	1	1	1
800-849		4	2	1	1	1	1							3	2	
850-899		2	1	1	2	3	1					1		1		
900-949					1	5	1				2	1		2		
950-999					1	1	1								1	
>1000					5	1	1							3	3	2
	220	476	273	641	196	93	317	232	541	129	**328**	**415**	**324**	**530**	**490**	**501**

	1996	Te Maari Stream 1997	1998	Ellesmere and tribs 2007	Whanganui 2005	Ruamahanga 2005	Arahura 1998	Tahakopa River 2004	Waimatuku River 2004	Wainakarua River 2004	Waipapa River 2004	Waitati River 2004	N	%
50-99	128	188	157	3	1	24	21		37	1	22	12	969	9.1
100-149	200	154	149	27	19	76	32	23	87	5	104	20	1764	16.6
150-199	186	164	170	29	17	74	60	77	35	7	79	11	1625	15.3
200-249	97	112	141	30	45	126	45	33	20	4	32	5	1452	13.6
250-299	40	52	68	44	42	75	31	5	22		17	4	1063	10.0
300-349	36	41	48	36	34	58	16	8	21		6	2	899	8.4
350-399	17	27	31	32	53	42	20	2	20		10	2	713	6.7
400-449	17	17	18	32	42	37	15	4	18		6	1	609	5.7
450-499	17	13	17	27	53	57	12		6		6	1	525	4.9
500-549	16	13	10	33	51	51	9		5		4		409	3.8
550-599	6	12	13	25	22	27	3	1	2		4	3	265	2.5
600-649	9	8		14	8	5			2		2		95	0.9
650-699	2	4	4	10	5	5	2		1	1	2	1	69	0.6
700-749	5	4		2	5	1	1				1		48	0.5
750-799	5	1	4	2	2	2							40	0.4
800-849		2	2	1	1	1	1						23	0.2
850-899	3			3	2	1	1					1	23	0.2
900-949			1	1	1	1	2						18	0.2
950-999	1		1			2	1				1		10	0.1
>1000	6	3					1						25	0.2
	791	**815**	**834**	**351**	403	665	273	153	276	18	296	63	10644	###

Table A-2: Length distributions of samples of electric-fished shortfin eels from sites around New Zealand.

	Horokiwi	Pigeon Bay	Te Maari	Company Creek	South Canterbury	Motu	Aparima		Horokiwi Stream			Pigeon Bay Stream			Te Maari Stream	
	2007	**2007**	**2007**	**2004**	**2010**	**2009**	**2002**	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**	**1996**	**1997**	**1998**
50-99	420	324	523	10	4	63	4	112	51	83	616	293	465	171	552	479
100-149	206	71	73	11	38	43	2	349	345	244	224	187	109	81	97	68
150-199	122	37	19	2	25	5	1	142	125	159	62	78	33	19	12	13
200-249	74	19	6		26	4	4	65	49	72	30	24	12	12	10	4
250-299	56	11	5		29	5	4	43	36	41	13	11	9	1	3	5
300-349	30	4	5		17	2	6	23	20	31	6	6	2	2	3	1
350-399	30	1	1		17	1	5	24	14	5	1	3		2	1	2
400-449	12				26	1	2	12	11	8	1	1	1			
450-499					29		5	8	3	4	1	3			1	1
500-549			1		37		2	2		1		1	1			2
550-599					31		5					1				
600-649					19		5				1	1				
650-699					9		2					1		1		
700-749				1	8	1	2	1							1	
750-799					2			1								
800-849					2									1		
850-899					1			1								
900-949														1		
	950	467	633	24	320	125	49	**783**	**654**	**648**	**955**	**610**	**632**	**291**	**680**	**575**

	Ellesmere and tribs	Whanganui	Ruamahanga	Arahura	Tahakopa River	Waimatuku River	Wainakarua River	Waipapa River	Waitati River		
	2007	2005	2005	1998	2004	2004	2004	2004	2004	**N**	**%**
50-99	6	75	84	15	1					4351	45.0
100-149	97	113	131	8				1		**2498**	25.9
150-199	99	62	28	3	1	1		2		1050	10.9
200-249	60	47	34	2		2		1		557	5.8
250-299	46	47	24	1						390	4.0
300-349	25	27	18	1		6				235	2.4
350-399	22	20	17			3				169	1.7
400-449	19	16	12							122	1.3
450-499	8	6	7			3				79	0.8
500-549	14	2	3			3				69	0.7
550-599	5	1	4			3	1			51	0.5
600-649	5		1			1			1	34	0.4
650-699	7		2							22	0.2
700-749	3		1							18	0.2
750-799	1		1			3				8	0.1
800-849										3	0.0
850-899										2	0.0
900-949										**1**	0.0
	417	416	367	30	**2**	**25**	**1**	**4**	**1**	**9659**	100

Table A-3: Total quantity (%/year) of eel exports by country, 2005-2010

Country	2005	2006	2007	2008	2009	2010	Grand Total
Australia	0.44	0.31	0.35	0.83	1.25	0.43	0.57
Belgium	40.11	36.34	26.15	25.88	17.27	6.07	19.65
Brunei	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Bulgaria	0.00	0.00	0.11	0.54	0.60	0.00	0.18
Canada	1.65	0.70	0.26	1.51	1.89	1.11	1.11
China	0.00	0.00	0.00	0.00	0.10	0.00	0.01
Cook Islands	0.00	0.00	0.00	0.00	0.00	0.00	0.00
France	0.60	3.66	3.33	2.15	2.51	0.94	2.00
French Polynesia	0.04	0.01	0.01	0.00	0.00	0.00	0.01
Germany	13.00	18.73	8.07	4.75	1.13	1.58	5.64
Hong Kong	2.83	3.67	3.87	3.68	6.42	2.46	3.57
Israel	0.36	0.00	0.00	0.00	0.00	0.00	0.03
Italy	0.00	3.74	1.52	0.00	2.53	0.91	1.28
Japan	0.00	0.02	0.00	0.01	0.01	0.00	0.01
Korea	6.52	3.80	38.80	39.95	45.69	75.22	47.51
Lithuania	0.00	0.00	0.00	0.00	0.00	0.25	0.09
Malaysia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mariana Islands	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	3.96	2.91	0.00	0.00	0.35	0.00	0.60
New Caledonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.87	1.03	0.50	0.39	0.53
Russia	0.00	0.00	0.00	0.00	10.34	2.88	2.39
Singapore	0.03	0.05	0.00	0.00	0.00	0.00	0.01
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Taiwan	10.23	7.75	3.64	2.65	1.76	1.23	3.24
UAE	0.31	0.23	0.12	0.00	0.04	0.02	0.08
UK	16.38	14.29	10.59	15.70	4.49	3.88	8.91
Ukraine	0.00	0.00	0.00	0.00	0.00	0.93	0.34
USA	3.53	3.78	2.31	1.29	3.12	1.70	2.26
Vanuatu	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Grand Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00